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APPLIED MECHANICS REVIEWS

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THE MECHANICS OF HIGH POLYMERS

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INTRODUCTION

THE mechanics of high polymers is that branch of knowledge and study in which the motions and deformations of a certain class of substances, called high polymers, are discussed with the aid of mathematical analysis. The forces which are responsible for the deformations are related to the latter by expressions which describe properties inherent to the substances studied. Once these relations are known and agreed upon, the study becomes a form of deductive science and is from then on mainly a matter of applied mathematics.

In the case of high polymers, the mathematical forms to be used for expressing the properties of the substances have not been fully agreed upon, and their formulation forms a significant part of this field of study. Because of this aspect, future progress in the mechanics of high polymers is more than a matter of applied mathematics; it is linked to progress in the understanding of the molecular mechanisms involved in polymer behavior.

This situation is beneficial to all those engaged in this study in that it encourages broadening of interests and enriches one's methods of research by the interaction of the work of scientists with varied backgrounds (1). Part of the motivation for writing this article consists of a desire to bring about more of such mutual awareness. However, the principal objective is to provide a short and systematic recounting of the concepts and developments which have led to the present status of knowledge in this field. Consequently, the present article will be mainly concerned with material behavior. This is in contrast to the conventional situation in mechanics where the development of methods of solution for particular types of problems are considered the principal part of a theory, much less importance being relegated to the initial assumptions concerning material behavior.

At this point, it is perhaps appropriate to define what is meant by a high polymer. (2) At the risk of oversimplification, high polymers may be defined to be substances formed by a (chemical) combination of smaller molecules (monomers) to yield an entanglement of long and relatively flexible chain molecules which attract each other by intermolecular forces. In structure, these polymers may be straight-chain or linear compounds, where one monomer is joined to the next in an extended chain; or crosslinked compounds, which are three-dimensional molecular networks. Linear polymers exist in either amorphous or semicrystalline forms.

These substances have a wide range of properties. Generally speaking, a sparsely crosslinked but coherent three-dimensional network results in soft and rubbery behavior with possibilities for very large but entirely recoverable deformations. As the amount of crosslinking is increased, the material becomes less deformable. The material also becomes less deformable as temperature is decreased. Crosslinked polymers are generally insoluble and infusible. In the case of linear polymers, there is no permanent three-dimensional network; polymer molecules are not only deformed but also diffuse past each other, resulting in large but not entirely recoverable deformations and in relaxation effects. For the present purposes, classification of polymer behavior will not be made on the basis of chemical structure, but rather on the phenomenological observation of whether mechanical relaxation is negligible or not.

NONRELAXING MEDIA (ENERGY AND ENTROPY ELASTICITY)

Some rigid polymers do not exhibit any relaxation effects. However, their deformation characteristics can be represented by classical elasticity and are thus not peculiar to polymer behavior. These substances will not be discussed in the following.

The type of behavior of interest here is "rubber elasticity." The principal feature is that of large elastic extensibility. It is now recognized that such behavior is not unique to natural or treated rubber, but is common to many other synthetic polymers which are, for this reason, referred to as "elastomers."

Since Meyer, v. Susich and Valko (3), numerous others have contributed to the understanding of the molecular basis for the large extensibility of rubber. A very good account of the developments in this field is given in a monograph by Treloar (4). He paraphrases Busse (5) to say that molecularly, there are three necessary conditions for the occurrence of rubber elasticity:

"1. The presence of long-chain molecules possessing freely rotating links.

"2. Weak secondary forces between the molecules.

"3. An interlocking of the molecules at a few places along their length to form a three-dimensional network."

Conditions 1 and 2 mean that, for any molecule, a segment between two consecutive junction points can take up a large number of possible geometrical configurations under the influence of thermal motion. The entropy of a segment, for any

specified position of its terminating junction points, is considered to be proportional to the logarithm of the number of available configurations. In the deformed state, the average entropy of the segments is smaller than that in the undeformed state, resulting in elastically stored energy and, hence, in retractive forces. The work of James and Guth (6), Wall (7), Flory and Rehner (8), and Treloar (9) all result in a stored energy function of the form

$$W = (1/2)NkT(\lambda_1^2 + \lambda_2^2 + \lambda_3^2 - 3)$$

where N is the number of segments per unit volume, k is Boltzmann's constant, T is the absolute temperature, and the λ's are the principal extension ratios. Derived on purely statistical grounds, this stored energy function is independent of the detailed molecular structure of the chain molecules in question.

The statistical theory of rubber elasticity has been successful in describing the behavior of elastomers to a very good extent not only with respect to deformation, but also with respect to changes in temperature. The theory may be expected to become inadequate whenever the stored energy function is dependent on internal energy, i.e., on details of molecular composition and structure, as well as on entropy; this may occur either upon increasing the number of crosslinks (vulcanization), decreasing the temperature and consequently thermal motion (transition to glassy state), or crystallization.

From the mechanics point of view, the large elastic deformations of rubbers are not different from the large elastic deformations of any other substance. The formulation of a suitable mathematical theory for such phenomena is, hence, quite logical and fairly straightforward (10). The specification of stress and strain is a matter of geometry. Certain combinations of these are independent of the choice of coordinate axes and are called stress and strain invariants. Since material behavior in turn must be independent of the choice of coordinate axes, it may be specified either in terms of a relationship linking the stress invariants and the strain invariants or in terms of a stored energy function which then must be a function of the strain invariants. Using a theory so formulated, critical experiments may be designed for evaluating the functions describing material behavior. These functions are then checked for other experimental cases. Further development of the theory becomes purely a matter of mathematics. Such a type of theory is phenomenological in nature, and not dependent on molecular models; but it gives indirect information on molecular mechanisms.

For rubbers, Mooney (11) and Rivlin (12) suggested that, although many other more complicated forms may be tried, actually the stored energy function

$$W = C_1(\lambda_1^2 + \lambda_2^2 + \lambda_3^2 - 3) + C_2(1/\lambda_1^2 + 1/\lambda_2^2 + 1/\lambda_3^2 - 3)$$

would be sufficient for representing rubber elasticity even for very large deformations. The experimental work of Mooney (11) and of Rivlin and Saunders (13) has substantiated this claim.

The nature of this article does not permit dwelling at length on refinements to the basic concepts outlined above. It is more important to move on to the discussion of relaxing media where current interest is greatest.

RELAXING MEDIA (VISCOELASTICITY)

If, in the statistical network model cited above, the crosslinks are removed from the three-dimensional network, an entanglement of weakly interacting long-chain molecules results. One can easily visualize that under stress such entanglements will not remain unchanged (*ad infinitum*) in the deformed state, but rather that the polymer molecules will diffuse past each other to increase the entropy and, hence, to minimize the stored energy. The resulting decay of retractive force is often called stress relaxation. Alternatively, if the crosslinks of a network were of a temporary nature rather than permanent, so that statistically a certain number of crosslinks can break and reform at any time, it is also easy to visualize the unrestrained molecules diffusing to undeformed states where they would once more form a network structure with surrounding chains. In both cases, the net result is the same: elastic deformation and material flow occur simultaneously. This unusual combination of material behavior is, hence, called *viscoelasticity*.

In contrast to the case of entropy elasticity where all the indications are that the results of the molecular theory helped to guide, in part, the choice of the stored energy function of the Mooney-Rivlin theory, the formulation of the phenomenological theory of linear viscoelasticity began about eighty years ago, and has since then been perfected to a high degree, preceding any molecular theory by at least seventy years.

The linear theory of viscoelasticity is based on the principle of superposition. Since the elastic solid and the viscous fluid are two well-known cases of physical behavior, it is natural to try to represent the behavior of a polymer by a mathematical model possessing both elastic and fluid properties. Such a combination gives rise to a natural time or *relaxation time*. For example, if a viscoelastic material is suddenly deformed by a certain amount, it will gradually flow to conform to the new deformed state which becomes its new natural state. The stresses necessary to make it conform to the new state consequently decrease with time, giving rise to stress relaxation such that $\sigma = \sigma_0 e^{-t/\tau}$ where σ is the stress at any time, σ_0 is the original value of the stress required to produce the deformation; τ is the relaxation time and is equal to η/μ where η is the viscosity of the system and μ its modulus.

More complicated materials can be represented by further superposition. In the most general case, linear material behavior is represented by a relaxation spectrum which may be a continuous or a line spectrum. In the case of an incompressible material, the stresses are expressed in terms of the strain rates by

$$\sigma_{ij} = \int_{-\infty}^{t} \Sigma 2\mu_n \{\exp[-(t+x)/\tau_n]\}[d\epsilon_{ji}(x)/dx]\,dx$$

It is well-known that the same behavior can be represented by a "retardation" spectrum instead of a relaxation spectrum, and that the one can be calculated from the other. A summary of the mathematical structure of the stress-strain relations of the theory of viscoelasticity has been given by Gross (14). More recently, extensive work on the further development and application of viscoelastic theory has been published. It is impossible to mention all or even most of the many ingenious solutions to particular problems.

It is worthwhile to point out that solutions of viscoelastic problems have often been facilitated by using an analogy method of solution. This method consists essentially of obtaining the Laplace transform of the elastic solution, replacing the shear modulus of the elastic solution in the transformed expression with a viscoelastic function, and obtaining the inverse transform of the altered expression. If the resulting expression satisfies the boundary and initial conditions of the physical situation, it is the unique viscoelastic solution to the problem considered. Sips (15) was probably the first to consider the possibility of this specific method of solution of viscoelastic problems although an equivalent form of operational method had been proposed before him by Tsien (16) for the case of a material with one relaxation time.

A paper of considerable importance to all those engaged in experimental work is that by Schwarzl (17) presenting a mathematical analysis of the accuracy obtainable from various types

of measurements, such as creep or relaxation measurements, dynamic modulus measurements, and measurement of damping.

Numerable experimental investigations have shown that the linear theory of viscoelasticity describes the deformation behavior of polymers quite well over large ranges of temperatures and frequencies, provided the deformations are small (18). This means that the linear theory of viscoelasticity can be applied to the propagation of high frequency harmonic disturbances through polymer solutions and molten polymers (19). The situation is much less clear if finite deformations have to be considered.*

It is interesting to note that although the concept of viscosity in a solid was accepted quite readily, and the consequent theory of linear viscoelasticity has been developed to a high degree of perfection, the concept of elasticity in a liquid was generally greeted with reservation by those engaged in mechanics research.

Three characteristic features of the flow of molten polymers can be demonstrated most readily: 1) The Weissenberg effect, i.e., the climbing of the liquid on the inner cylinder in Couette flow with free surface; 2) the swelling of the free stream issuing from a tube in Poiseuille flow; and 3) the decrease of viscosity with increase in shear rate in Couette flow. Hence, the validity of linear viscoelastic theories can most easily be judged by their ability to accommodate these three effects.

Attempts have been made to explain these features by means of fluid dynamics theories which do not involve elasticity, at least not explicitly. The Reiner (20) and Rivlin (21) theories consider a "slightly" viscoelastic fluid in that they introduce implicitly a relaxation time in the quadratic terms only. Solutions for Couette flow and Poiseuille flow show that normal stresses are required to maintain simple shear flow. Thus, in Couette flow, pressures must be supplied to the planes perpendicular to the cylinder axes. In the absence of these pressures, the free surface will tend to rise, the effect being greatest at the inner cylinder. Similarly, in Poiseuille flow, the radial pressure in the stream at the plane of exit from the tube is found to be not zero. Hence, the stream will tend to swell after leaving the tube. Both theories quoted are actually very much alike, and thus equally successful in explaining these features qualitatively; quantitative checks are still lacking. The Reiner-Rivlin theories, besides being formulated for only one relaxation time, do not make any explicit statement concerning the magnitude of the elastic deformations involved. The inherent difficulties of such specifications are quite easy to understand. No direct connection between the elastic deformation of the liquid, i.e. of the molecules, and its gross deformations exists, since, in actual fact, these elastic deformations are determined by the state of stress and the stress history of the liquid. Attempts to use elasticity strain components have not always been very successful. For example, both Weissenberg (22) and Fromm (23) use strain components ϵ_{ij} without defining them. In an attempt to predict the non-Newtonian nature of the viscosity of a fluid with one relaxation time, Fromm recognizes the fact that such fluids have "memories," and stress-strain rate relations are to be written in terms of rotating convected material coordinate systems. Although he considers only the rotation of the stress tensor and neglects the effect of rotation on the strain tensor, he arrives at the result that the viscosity decreases with shear rate in steady-state simple shear flow. Loring (24) has also treated the case of a fluid with one relaxation time in a more general manner but found no dependence of viscosity on shear rate.

*The situation is significantly more complicated if the material is clearly not linear. A good survey of investigations of such materials has been made by Marin. AMR 4, Rev. 633.

The most promising molecular theories for the description of relaxing media were formulated by Green and Tobolsky (25), Scott and Stein (26), Rouse (27), Bueche (28), and Zimm (29). The first two theories are based on the concept of a nonpermanent three-dimensional molecular network. When in a strained state, secondary bonds break, disrupting the network temporarily. The segments involved move very rapidly into their most probable configuration distribution where they reform crosslinks with the neighboring molecules. This theory is capable of describing finite deformations of relaxing media with one relaxation time in terms of the average length of the molecule chain between crosslinks and the average lifetime of crosslinks. Lodge (30) has, somewhat arbitrarily, superimposed these nonlinear terms in the manner of a linear Boltzmann superposition. He is able to predict the presence of normal stresses in the case of simple shear flow, but is not able to predict the non-Newtonian nature of the viscosity.

Rouse, Bueche, and Zimm have considered the case of dilute solutions of linear polymers. These theories are linear theories and apply strictly to small deformations only. It turns out that, although the molecular models used in the three theories are essentially the same, the Rouse and Zimm theories are incapable of predicting the shear rate dependence of the viscosity.

Recently Pao (31) has proposed an explanation for this discrepancy. All three theories are, strictly speaking, only valid for the case of small deformations. In practice, however, they have been extrapolated to steady-state simple shear flow which involves extremely large over-all deformations. The Rouse and Zimm methods of extrapolation use the solutions for a harmonic disturbance of frequency ω: the case of steady-state flow is taken to be that for which $\omega \to 0$. In the Bueche theory, the assumption is made that in steady-state simple shear flow, which is a rotational flow, the polymer molecules actually revolve, on the average, like rigid spheres; that is, even a steady shear disturbance subjects the molecules to harmonic tensile and compressive forces, the shear rate being equal to an equivalent frequency. In such terms, it can easily be shown that the "viscosity" of a generalized viscoelastic material decreases with frequency.

The treatment by Bueche is probably adequate for calculating the viscosity of dilute solutions, but brings forth some perplexing questions when applied to bulk polymers, as done recently (31). A bulk polymer, even in the molten state, behaves more and more like a rubber as the rate of shear is increased. Thus, although the viscosity may decrease, the stress necessary to shear the polymer increases with displacement and steady-state flow may never be reached. This limitation is not contained in Bueche's theory.

Pao (31) has developed a theory for the large deformations of a generalized viscoelastic fluid taking into account the memory, and hence an "induced anistropy" of the liquid, by use of rotating convected material coordinate systems, and the definition of material strains. From this treatment, the decrease of viscosity with increase in shear rate in the case of steady-state shear flow emerges as a phenomenon common to all viscoelastic liquids and independent of the molecular models involved. This opens the way to the mutual and experimental appraisal of the molecular theories by Rouse, Bueche and Zimm.

INDUCED MORPHOLOGICAL CHANGES

The preceding sections have given evidence of the difficulties encountered even in formulating theories which can account for some of the simpler characteristics of high polymer mechanics. The situation becomes more complicated when deformations induce morphological changes in the material, as is

observed for semicrystalline polymers. **These substances** differ from the amorphous viscoelastic materials discussed above in that most of them exhibit a temperature- and rate-dependent yield point followed by large nonrecoverable deformations at nearly constant force; this "cold-draw" is followed by a "strain-hardening." So far, no satisfactory mathematical or molecular theory has been advanced for yield and cold-draw, even though many qualitative explanations have been proposed.

The apparent similarities between the stress-strain behavior of semicrystalline polymers and ductile metals have been pointed out repeatedly. This suggests that plasticity theories developed for the latter might be applied to semicrystalline polymers. Some limited progress can be expected from this approach. There exist, however, two noteworthy differences between the two classes of materials, from molecular considerations. As Schurr (33) points out:

1) Slip in polymers can occur only between lattice planes which are parallel to the chain molecules, whereas in metals, slip can occur in all lattice planes.

2) Slip between lattice planes in a polymer may cause tensions in the molecules so that the material can recover by a reverse slip of lattice planes, whereas in metals, slip between planes is always permanent.

These differences in molecular mechanisms will undoubtedly be reflected in differences in the structure of any mathematical theory. However, the complexity of the phenomena may be expected to become mitigated as fuller use is made of the thermodynamics of irreversible processes than heretofore.

SUMMARY

In summary, successful theories have been developed for deformations of rubbers, viscoelastic solids (small deformations), and viscoelastic liquids (large deformations), but much work remains to be done especially in the case of liquids. Systems where deformations affect structure appreciably are extremely difficult and have as yet not been treated theoretically. One is, hence, led to the conclusion that fruitful progress in the mechanics of high polymers can be expected from a careful definition of the "elasticity" encountered in viscoelastic liquids, from the development of mathematically tractable theories for the flow of viscoelastic liquids which can still be interpreted in terms of molecular parameters, and from a systematic phenomenological treatment of the thermodynamics of irreversible systems designed to accommodate all the known features of the behavior of semicrystalline polymers.

It is a challenging aspect of this rapidly developing field of scientific endeavour that the recognition of new problems as well as progress in the solution of known problems will depend upon the results and close cooperation of many branches of polymer science.

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"Letters to the Editor" and "Books Received for Review" now appear after the reviews.

Theoretical and Experimental Methods

(See also Revs. 1704, 1708, 1714, 1715, 1732, 1734, 1737, 1739, 1758, 1762, 1766, 1767, 1814, 1823, 1878, 1880, 1887, 1890, 1941, 1964, 1965, 1993, 2015, 2043, 2051, 2054, 2057)

1676. Clerc, D., Mathematical theory for a new mechanical process for the solution of systems of linear equations (in French), *Rech. aéro.* no. 44, 51–54, Mar./Apr. 1955.

Method described is essentially the Gauss elimination method, with an augmented matrix to facilitate handling several right-hand sides simultaneously. After the matrix has been reduced to triangular form, the back substitution can be carried out either in the forward or reverse direction. Method is set forth as a systematic iteration suitable for digital computers. The use of check sums is not described, but these could be incorporated.

C. C. Gotlieb, Canada

1677. Janin, R., Solution of systems of linear algebraic equations of high order with the aid of mechanical methods (using an electronic computer) (in French), *Rech. aéro.* no. 44, 47–50, Mar./Apr. 1955.

Paper describes application of method in preceding review to an electronic digital computer with punched card input output. Solution of a system of order 40 requires 6500 cards and 12 hours, as opposed to previous method requiring 180,000 cards and 135 hours. Figures apply for a nonscientific machine with 32 lines of program and 8 storage locations (but with floating point operation). For a machine with 64 program lines and 7 storage locations, two hours would be required.

C. C. Gotlieb, Canada

1678. Ludwig, R., Practical solution of biquadratic equations with only complex roots (in German), *ZAMM* **35**, 11, 401–405, Nov. 1955.

Assuming the roots of the equation are complex only and substituting them by means of their components in Gauss' plane, two equations are

obtained, the resultant of which has roots which are in close relation to the real parts of the complex solution of the original equation. Approximate calculation of roots makes use of the complete Horner scheme and Newton's method. This method is not suitable for solution of equations of higher order than four because of the extensive computational work.

V. Kopřiva, Czechoslovakia

Book—1679. **Salekhov, G. S., Summation of series** [Vychisleniye ryadov], Moscow, Gos. Izdat. Tekh.-Teor. Lit., 1955, 143 pp., 3r. 60 k.

The monograph under consideration is divided into 5 chapters and an appendix with 38 subsections. It brings a common method of establishing several criteria of convergence, of estimating the remainders, and of improving the convergence of series.

First chapter is based upon the Kummer transformation. It gives some general criteria of convergence and also presents the corresponding methods of speeding up the convergence of series. The usual sufficient conditions by d'Alembert, Raabe, Gauss, Cauchy, etc., seem to be only special cases of the author's general conception. The following two sections illustrate on various concrete problems the theory given in the first chapter.

Of special significance for mathematical physics and engineering science is the fourth main part about increasing the convergence of series in special functions (Hermite, Legendre and Tschebyshev polynomials, Bessel functions, etc.). Author's methods are much more general than the well-known procedure given by A. N. Krylov for the theory of trigonometric series. Fifth chapter brings several integral estimates both for finite sums and for infinite series. The appendix extends theoretical methods of the first three chapters to double series.

Paper is good, print careful. This fine book is recommended to engineers and physicists.

V. Vodička, Czechoslovakia

1680. **Vernotte, P., The ideal interpolation and its effective numerical calculation** (in French), *Publ. sci. tech. Min. Air, France.* no. 300, 74 pp., 1955.

Given an infinite sequence of numbers $y_0, y_1, y_2, \ldots$, author defines as ideal interpolation a rule for finding a function $f(x)$ which has the values $y_0, y_1, y_2, \ldots$ for $x = 0, 1, 2, \ldots$ and which has the following property: if the y_k are replaced by new values $\varphi(y_k)$ for any function φ, $f(x)$ is replaced by $\varphi[f(x)]$. Without stating so explicitly, author uses the postulate that $f(x)$ be continuous.

Author does not seem to realize that in this sense, for arbitrary φ, such an interpolant $f(x)$ exists only in trivial cases; specifically, a continuous $f(x)$ only in the case where all y_k are equal and f is constant. (One sees this by considering a function φ which leaves all y_k unchanged but changes some other value of f). While he recognizes that $f(x)$ need not exist for any sequence $\{y_k\}$, author tries to determine what should be the nature of $\{y_k\}$ in order to insure existence of $f(x)$; conjectures that the question is connected with the signs of successive tabular differences; and seems to believe that, for example, the sequence $y_k = k!$ can be "ideally" interpolated by the gamma function. In all attempts at proofs he only deals with specially chosen transformations φ, such as squares or cubes. He finally discusses at great length an interpolating algorithm claimed to lead to ideal interpolation. While the claim is invalid in view of the foregoing, the algorithm may be of some value.

F. L. Alt, USA

1681. **Quade, W., The interpolation of real functions** (in German), *ZAMM* **35**, 4, 144–156, Apr. 1955.

Lagrange's interpolation formula and Newton's formula, as a special case of Lagrange's, have disadvantages which make them unsuitable for practical purposes. The first disadvantage appears in the fact that this interpolation formula tends not toward the interpolated function when the number n (the number of equidistantial ordinates) is infinitely increased. Another deficiency is still more important from the practical point of view. Should the interpolation be accomplished with $2n + 1$ ordinatae, corresponding to equidistant abscissae $x_0, x_1, \ldots, x_{2n}$, this interpolation formula becomes a polynomial of the degree $2n$. Should now f_n, which lies in the middle of the ordinates, be slightly altered by δf_n, and supposing that all other ordinates remain unchanged, then $P(x)$ will change extraordinarily for the value of $x_0 + \dfrac{h}{2}$, in the middle of first interval. The difference increases rapidly already for $n = 10$, i.e., for 21 ordinates.

The disadvantages in question can be avoided by using the method of trigonometrical interpolation. The function employed consists of a polynomial and of a definite trigonometrical sum.

J. Marinković, Yugoslavia

1682. **Berger, E. R., An improvement of the Sterling formula** (in German), *ZAMM* **35**, 1/2, 69–70, Jan./Feb. 1955.

1683. **Vogel, W., A graphical method for the solution of linear differential equations of the second order** (in German), *Ing.-Arch.* **23**, 2, 119–121, 1955.

Method is given for plotting the solution of initial-value problems point by point without use of the osculating circle; two examples are included.

H. Witting, Germany

1684. **Brillouet, G., Representations of certain integrals of differential equations** (in French), *C. R. Acad. Sci. Paris* **240**, 22, 2113–2115, June 1955.

For the inhomogeneous linear differential equation of arbitrary order but with constant coefficients, the right hand side of which is a general power of the independent variable, a particular solution is given in the form of a certain definite integral, analogous to Laplace integral representation. In the special case that the disturbing term is a negative entire power of the independent variable, the connection between this solution and that to be gained by Lagrange's method of variation of the constant of integration is discussed.

H. Behrbohm, Sweden

1685. **Young, D. M., Ordvac solutions of the Dirichlet problem,** *J. Assn. Comp. Machy.* **2**, 3, 137–161, July 1955.

Paper describes a program for the numerical solution of Laplace's equation in regions with rectilinear boundaries. It deals with the finite difference approximation to the differential equation using up to 400 mesh points and solves by an iteration technique, using a device to give an accelerated rate of convergence as compared with straightforward use of Gauss-Seidel. The effectiveness of the acceleration depends on a good choice of a parameter, and much of the paper is concerned with the empirical determination of a good value during iteration. Reviewer believes that although much work has been done in this field elsewhere this is the first systematic account in the literature.

J. H. Wilkinson, England

1686. **Tomlinson, N. P., Horowitz, M., and Reynolds, C. H., Analog computer construction of conformal maps in fluid dynamics,** *J. appl. Phys.* **26**, 2, 229–232, Feb. 1955.

The application of a Geda-type analog computer to the determination of air-foil shapes and flow patterns in ideal fluids is described. The development of the equations to determine the computing circuit is outlined and the computing circuit for construction of conformal maps is shown.

Accuracy of the method is assessed by comparison with card-programmed and hand-computed results and found to be comparable. A discussion of the time required to set up and compute a typical problem is given, and it is shown that, where several shapes are to be examined, there is a definite time saving with the analog method compared to hand-computed and card-programmed procedures.

F. C. Hooper, Canada

1687. **Murray, C. T., and Hollway, D. L., A simple equipment for solving potential and other field problems,** *J. sci. Instrum.* **32**, 12, 481–483, Dec. 1955.

A method is described for the solution of two-dimensional field problems using, as an electrical analog, current flow in a sheet of ordinary paper. As the paper resistivity is high, pencil lines are used as electrode boundaries. Details of the circuit and construction of a suitable equipment are given and considerations affecting accuracy are discussed.

From authors' summary

1688. **Fox, P. A., Perturbation theory of wave propagation based on the method of characteristics,** *J. Math. Phys.* **34**, 3, 131–151, Oct. 1955.

Perturbation solution for plane wave propagation is given in terms of both characteristic parameters (rather than one, as in previous work), yielding parametric solutions for time and space variables. Results are

not limited to simple waves and have the advantage of describing wave up to and somewhat beyond point of shock formation. Examples treated are development of shocks from initial sinusoidal distribution of density disturbance in closed cylinder, and mass flow in semi-infinite cylinder bounded by oscillating piston. Comparison is made with solution given by Riemann function. J. J. Gilvarry, USA

Book—1689. Stratton, J. A., Morse, P. M., Chu, L. J., Little, J. D. C., and Corbato, F. J., Spheroidal wave functions, New York, The Technology Press of M. I. T., and John Wiley & Sons, Inc.; London, Chapman and Hall, Ltd., 1956, xiii + 613 pp. $12.50.

Volume presents tables designed to assist applied worker in solution of wave problem in spheroidal coordinates with same ease as is now possible for rectangular, circular, cylindrical, and spherical coordinates. A previous paper by L. J. Chu and J. A. Stratton, "Elliptic and spheroidal wave functions" is reprinted from *J. Math. Phys.* **20**, 3 Aug. 1944. This derives key results and expressions useful for computation of the functions. The actual tables, however, follow the notation and normalization of Morse and Feshbach, "Methods of theoretical physics" [AMR **8**, Rev. 3265]. (For a detailed study of the subject together with applications, see the recent work of Meixner and Schäfke [AMR **8**, Rev. 1256].) Method of computation is described and notation of two noted sources are compared. Computations were performed on Whirlwind, and a brief description of programming is presented. For prolate and oblate spheroidal wave functions, tables give coefficients of the radial function of first kind in spherical Bessel functions, and coefficients of the angular function of the first kind in associated Legendre functions. Some tables of these quantities were previously given in the volume, "Elliptic cylinder and spheroidal wave functions," by J. A. Stratton, P. M. Morse, L. J. Chu, and R. A. Hutner, Wiley, New York, 1941. However, present tabulations are much more extensive in both range of parameters and number of significant figures. Y. L. Luke, USA

Book—1690. Anonymous, Tables of sines and cosines for radian arguments, Washington D. C., U. S. Dept. Comm., Nat. Bur Stands. appl. Math. Ser. 43, 1954, xi + 278 pp. $3.

This is a reissue of volume published in 1940. Range of main table has been slightly extended so that functions are given to 8d for $x = 0$ (0.001) 25.2. A supplementary table useful for interpolation has been changed. A more useful table of conversion factors (radians to degrees and vice-versa) is provided. Y. L. Luke, USA

Book—1691. Anonymous, Table of hyperbolic sines and cosines, Washington, D. C., U. S. Dept. Comm., Nat. Bur. Stands. appl. Math. Ser. 45, 1955, v + 81 pp. $0.55.

Table supplements pertinent values given in AMS no. 36 [AMR **7**, Rev. 1708]. Title functions are given to nine significant figures for $x = 2.0$ (0.001) 10.0. Y. L. Luke, USA

Book—1692. Schutte, K., Index of mathematical tables [Index Mathematischer Tafelwerke und Tabellen], München, R. Oldenbourg, Publishers, 1955, 143 pp. DM 14.50.

Author gives the history of project in preface. Well-known work by Fletcher, Miller, and Rosenhead ["Index of mathematical tables," McGraw Hill, 1946; called "FMR"] did not reach author until his own work was brought to a temporary conclusion. Author's work could not be resumed until 1953 when previous manuscript was enlarged to include some of the vast material published subsequent to data in FMR. Author lists several items which he consulted to expand work, and, unfortunately, *the* source journal, *Mathematical Tables and Other Aids to Computation* (*MTAC*), is conspicuous by its absence. Standard tables are listed, that is, those published by National Bureau of Standards, British Association for Advancement of Science, Harvard Computation Laboratory, etc. Tables from journals are also recorded, but listings are by no means complete.

Standard tables are not difficult to locate, but many short tables not known by a name, and which can only be listed by function, are omitted. The problem of indexing has been previously discussed by reviewer ["Numerical analysis," AMR **8**, pp. 309–311, 1955] and need not be repeated here. Suffice it to remark that the serious worker will find little comfort in present volume and will do well to always consult FMR and *MTAC*. Knowledge of errata in tables is important; this is omitted—a consequence of unawareness of *MTAC*.

Five of the fifteen chapters are devoted to tables arising in physics, chemistry, astronomy, meteorology, etc., and are essentially material depending to some extent on experimental data. This information should be useful to many workers, but it calls for remark that these are not mathematical tables in the ordinary sense, as the functions tabulated are not of a universal character. Y. L. Luke, USA

1693. Adams, D. P., Three-dimensional nomograms, *Prod. Engng.* **26**, 8, 186–191, Aug. 1955.

Three-dimensional nomograms require the determination of the intersection of a plane with a figure in three dimensions. This may be accomplished in a two-dimensional diagram by orthographic projection of the figure onto one of the planes determined by two axes. Three variants of this are illustrated. The reduced quintic (no fourth power) is discussed, and a nomogram has been prepared by the author.
G. W. King, USA

1694. Powell, W. E., Rectangular nomographs—four sides to an equation, *Prod. Engng.* **27**, 3, 192–195, Mar. 1956.

1695. Prince, M. D., Linear sine paper for engineering applications, *Prod. Engng. (Product Design Handbook for 1956)*, **26**, 11, A12–A13, Oct. 1955.

1696. Prince, R. K., Queueing-Up, *Prod. Engng.* **26**, 12, 188–192, Nov. 1955.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 1712, 1809, 1826, 1850, 1974, 2058, 2067, 2072)

Book—1697. Rosenthal, E., and Bischof, G. P., Elements of machine design, New York, McGraw-Hill Book Co., Inc., 1955, vii + 233 pp. $4.50.

This book is rather short, 233 pages, and is written for use in technical high schools and technical institutes. The subject matter is conventional; shafts, couplings, springs, belts, and the like. There are a number of statements in the text with which the critical reader may take exception. Many of these, no doubt, result from the necessary brevity of the treatment and the elementary point of view. W. J. Carter, USA

1698. Keator, F. W., and Crossley, F. R. E., Analyzing dimensional and velocity characteristics of 3-D mechanisms, *Mach. Design* **27**, 204–209, Sept. 1955.

The 3-D mechanisms considered here are spherical quadrilaterals or four-bar linkages on the surface of the sphere; the axes of the four hinges pass through the center. The angles between the links for any position of the driving link are determined by solving spherical triangles. Sample calculations using the methods of spherical astronomy are given. A graphical method of obtaining approximate checks employs the trammel method of drawing ellipses which are the projections of the great circles. The instantaneous motions correspond to the rolling of bevel gears. M. Goldberg, USA

1699. Wolford, J. C., Four-bar linkages; as function generators, *Prod. Engng.* **26**, 10, 166–171, Oct. 1955.

Two numerical examples based on Sieker's analysis are given as illustrations for the design of the four-bar linkages to be used as function generators for a limited range of motion. L.-W. Hu, USA

1700. Volterra, E., The equation of motion for curved elastic bars deduced by the use of the "method of internal constraints," *Ing.-Arch.* **23**, 6, 402–409, 1955.

Partial differential equations are deduced, assuming plane sections remain plane. Special case of constant curvature is treated, but method is applicable to general case. Mathematical level of paper is high for most engineers. D. C. Johnson, England

1701. Bowden, F. P., and Rowe, G. W., The adhesion of clean metals, *Proc. roy. Soc. Lond. (A)* **233**, 1195, 429–442, Jan. 1956.

By considering the elastic springback of a sphere slightly impressed

into a flat surface, an equation is found for the effect of tangential stressing without slip on the force required to separate the surfaces. Relations between shear and normal stresses were taken directly from the von Mises yield criterion, assuming infinite surfaces; reviewer recommends Green's relations for sharp and deep notch [AMR 7, Rev. 3210]. Experiments at 10^{-3} and 10^{-5} μ vacuum on gold, nickel, platinum, and silver agree with authors' theoretical equation, but show more adhesion than predicted from Green's relations. Perhaps this discrepancy is due to presence of tension in some welded junctions after tangential micro-sliding. Higher temperature promotes annealing, reduces flow stress and hence springback, and increases contact area; relation to annealing and sintering temperatures is shown.

Paper is an important contribution to contact mechanics.

F. A. McClintock, USA

1702. **Saelman, B., How force requirements and design for strength are influenced by friction in mechanisms,** *Mach. Design* 28, 4, 123–126, Feb. 1956.

In the load analysis of mechanisms with rotating link members, the effects of frictional forces are often difficult to evaluate. Members can be joined with bolts, bolts and plain bearings, or bolts and antifriction bearings. Friction may be helpful or detrimental to the design, depending on the function being considered. Examples are given in the paper which provide methods of approach for three representative cases.

From author's summary

Servomechanisms, Governors, Gyroscopics

(See also Revs. 1905, 1908, 1926, 1927)

Book—1703. **Thaler, G. J., Elements of servomechanism theory,** New York, McGraw-Hill Book Co., Inc., 1955, x + 282 pp. $7.50.

The book is designed as a text for undergraduate students and for interested engineers. Apart from the discussion on pedagogical merits of treatment of the theory of servomechanisms before acquainting student with the theory of functions of complex variables, the book serves the purpose well.

A few new approaches are adopted. System equations and transfer functions are dealt with by the circuit theory, not by the commonly used Laplace transformation; polar and logarithmic treatment of design and analysis is dealt with at the same time to indicate the similarities of both methods. Although primarily the loop systems are discussed, the extension to multiloop systems is indicated. More advanced topics are discussed in the appendix in order to acquaint the reader with a possible extension of the theory. Examples are selected so that they have all the exhaustive features of general cases. There is a well-selected bibliography to every chapter.

The author indicates that he used this book successfully in teaching the theory of servomechanisms over a period of several years. It is certainly highly recommended for anyone who plans to introduce this course for undergraduate seniors, or for a group of engineers.

R. M. Evan-Iwanowski, USA

1704. **Huss, C. R., and Donegan, J. J., Method and tables for determining the time response to a unit impulse from frequency-response data and for determining the Fourier transform of a function of time,** *NACA TN* 3598, 38 pp., Jan. 1956.

In the theoretical analysis of networks, direct and inverse Fourier transforms are commonly used to determine the frequency response due to a given input, and vice versa. The evaluation, however, is often very difficult or time consuming because of the complexity of the integrals involved. Authors suggest, therefore, a new method in which a staircase type of function is used to approximate either the given input or the given frequency response.

Using $h(t) = 2/\pi \int_0^\infty R[H(i\omega)] \cos \omega t \, d\omega$ when the frequency response is given, the approximation of the time response to a unit impulse $h(t)$ results in an equation in which the function $(1/z) \sin z \cos (2n-1)z$ occurs; this function has been tabulated ($1 \leq n \leq 50$ and $0.00 \leq z \leq 2.50$). In case the input is given, the approximation of the direct Fourier transform of a time function results in a complex equation, the real part of which contains the above function and the imaginary part the function $(1/z) \sin z \sin (2n-1)z$; the latter function has also been tabulated ($1 \leq n \leq 50$ and $0.00 \leq z \leq 1.00$).

This method can be used for linear functions for which Fourier transforms exist. Computations are considerably facilitated and desk-calculation time is greatly reduced by use of the outlined procedures and the accompanying tables. The accuracy of the method (which can be improved by increasing the number and decreasing the size of the intervals) is shown in several examples. As a specific application, the evaluation of Duhamel's integral is shown when the input is given by a triangular impulse and the time response to a unit impulse is determined by the above method.

C. B. Ludwig, USA

1705. **Johnson, E. F., How to use frequency response in chemical process control, Part I.,** *Chem. Engng. Prog.* 51, 8, 353–356, Aug. 1955.

1706. **Johnson, E. F., The use of frequency response analysis in chemical engineering process control, Part II.,** *Chem. Engng. Prog.* 52, 2, 64-F–68-F, Feb. 1956.

1707. **Caughey, T. K., and Hudson, D. E., A response spectrum analyzer for transient loading studies,** *Proc. Soc. exp. Stress Anal.* 13, 1, 199–206, 1955.

The design and operation of a response spectrum analyzer for transient excitation studies is described. Electric analog techniques are used, with a series inductance, capacitance, and resistance circuit forming a direct passive analog to a mechanical system. The circuit arrangement permits a determination of system response for a sequence of frequencies at constant damping, and provision is made for obtaining zero damping in the circuit. An arbitrary function generator of the variable width film photoelectric type is described. The results obtained with the function generator-spectrum analyzer system for a half-sine pulse are compared with the mathematically obtained exact answers for zero damping, and the accuracy of the system is shown to be satisfactory for most engineering applications.

From authors' summary

1708. **Gladwin, A. S., Stability criteria for an electrical or mechanical system with distributed parameters,** *Brit. J. appl. Phys.* 6, 11, 400–402, Nov. 1955.

This paper studies stability of time delay systems representative of examples such as a simple two-stage feedback amplifier loaded with a mismatched transmission line, an oscillator connected to a resonant load through a uniform transmission line, or a steam or fuel input control not near the engine. The nonlinear characteristic equation is $C_0 + C_1 z + (C_2 + C_3 z) \operatorname{tank} z = 0$ in which the C's are real constants. The real and imaginary parts of the equation are studied on the imaginary axis iy. A necessary and sufficient condition for stability is that C_3/C_0, C_1/C_3, $(\pm C_2/C_1 + y_1 \operatorname{Cot} y_1)$ and $\mp C_1$ shall all be greater than zero when $C_0 \neq 0$ and y_1 is the smallest positive root of $y \tan y = C_0/C_3$. When $C_0 = 0$ and $C_3 \neq 0$, then it is necessary and sufficient that $(C_1 + C_2)/C_3$ is greater than zero.

M. G. Scherberg, USA

1709. **Reswick, J. B., Determine system dynamics—without upset,** *Control Engng.* 2, 6, 50–57, June 1955.

First step in constructing a mathematical model of a control system is to determine its dynamic characteristics. Classical method for doing this is to submit the system to sinusoidal disturbances of several frequencies, or to a step disturbance, or to an impulse, and record the system response. In every case the system is being disturbed and the quality of the product impaired as long as the investigation is under way. In many cases this cannot be tolerated.

However, disturbances actually occur during normal operation. It ought, therefore, to be possible (provided the system is linear) by recording the actual variations of two input and output quantities in the system to obtain complete information about the system characteristics, in the form required by classical theory.

Author explains very clearly how this can be done, describes the instrumentation (Delay Line Synthesizer) which he has designed to that effect, and gives an example of application to a refinery distillation column with automatic controls. Essential mathematical tools are autocorrelation and cross-correlation functions, which are explained in

simple terms with very helpful figures. Bibliography is included. Paper is strongly recommended reading. P. Le Corbeiller, USA

1710. Pack, G. J., and Phillips, W. E., Jr., Analog study of interacting and noninteracting multiple-loop control systems for turbojet engines, *NACA Rep.* no. 1212, 13 pp., 1955.
See AMR **8**, Rev. 25.

1711. List of Russian literature on automatic control and related problems (in Russian), *Automatika i Telemekhanika* **16**, 2, 219–224, 1955.

1712. Chatterton, J. B., Fundamentals of the vibratory rate gyro, *Trans. ASME* **78**, 1, 123–125, Jan. 1956.

Author develops theory of recently announced Sperry "gyrotron," a rate gyro based on a torsionally suspended vibrating system of the tuning-fork type. Angular velocity about axis of torsional suspension produces oscillatory torque about that axis, output (torque) being suppressed carrier modulated. Output is measured as torsional velocity. Equations for this are derived for case of equal suspension and vibration frequencies, suspension being damped. Approximate transfer functions are derived, and it is shown that performance tends to improve with reduction in size.

Components due to angular acceleration can be completely removed during demodulation. Transient overshoots tend to be very high, but can be suppressed if instrument mounting filters out frequencies in neighborhood of torsional resonance.

Author states that this type of instrument is still in experimental stage, but that its future is promising. R. Hadekel, England

Vibrations, Balancing

(See also Revs. 1924, 2020, 2073)

Book—1713. Timoshenko, S., and Young, D. H., Vibration problems in engineering, 3rd ed., New York, D. Van Nostrand Company, Inc., 1955, ix + 468 pp. $8.75.

Present edition of this widely used and authoritative text amounts to a nearly complete revision of the previous edition. The chapter on nonlinear vibrations has been greatly expanded and modernized and now amounts to a quite satisfactory introduction to the engineering treatment of this important subject. Other chapters have been reorganized and much new material added. Many references to recent work have been added throughout the book. The increased emphasis placed on transient phenonema is gratifying.

Authors have chosen in the present edition to employ d'Alembert's principle for formulating equations of motion rather than the Lagrangian approach, as in previous editions. Reviewer cannot agree that this is an improvement. It would seem that the Lagrangian formulation is even more important in engineering practice today than previously and that employment of the admittedly more direct, but often more cumbersome, d'Alembert approach will not equip the student adequately. Each teacher will have to resolve the issue according to his own predilections.

Format and reproduction are substantially equivalent to previous editions. Reviewer could detect no misprints, but notes that Eq. (a), p. 126, is in error.

Lucid style of the authors, which needs no recommendation, is even more evident in this work. Few books meet so successfully the requirements for both classroom and reference use. Without question, this book remains one of the most complete and authoritative treatments of vibration problems in engineering, and the appearance of this new edition will be heartily welcomed by all. H. N. Abramson, USA

1714. Bottema, O., On the stability of the equilibrium of a linear mechanical system, *ZAMP* **6**, 2, 97–104, 1955.

Author extends H. Ziegler's results and derives a number of conditions given by W. Thomson and P. G. Tait in studying the general case of linear systems with two degrees of freedom. The general systems are transformed to

$$\ddot{x} + a_{11}x + py + b_{11}\dot{x} + (b_{12} + \omega)\dot{y} = 0$$
$$\ddot{y} - px + a_{22}y + (b_{12} - \omega)\dot{x} + b_{22}\dot{y} = 0$$

and examined for stability over the range of all parameters. In particular, it is shown that a frictionless system having circulatory and gyroscopic forces (i.e., $b_{ij} = 0$, $p \neq 0$, $\omega \neq 0$) cannot be stable. Except for specified exceptions, a similar system having three degrees of freedom is also unstable. A. I. Bellin, USA

1715. Livesley, R. K., The equivalence of continuous and discrete mass distributions in certain vibration problems, *Quart. J. Mech. appl. Math.* **8**, 3, 354–360, Sept. 1955.

Paper discusses error introduced when the natural frequencies for systems having an infinite number of degrees of freedom are found by replacing the systems by equivalent systems of concentrated masses and inertias. Simple cases of transverse vibration of elastic strings and torsional vibration of uniform bars are considered first. Frequency error is obtained for case of uniform, simply supported beam in transverse vibration. Author concludes that, if continuous mass of beam is replaced by equally spaced concentrated masses, the errors in natural frequencies are proportional to the inverse fourth power of the number of segments into which the beam is divided. P. G. Jones, USA

1716. Cox, H. L., and Denke, P. H., Stress distribution, instability, and free vibration of beam grid-works on elastic foundations, *J. aero. Sci.* **23**, 2, 173–176, Feb. 1956.

Differential equation for a plane rectangular grid work of pin interconnected beams is presented. Parallel beams are presumed to be identical, but may have variable stiffness. Grid spacings are presumed uniform. Nonuniform loads parallel and perpendicular to the plane of the grid are accounted for, as is a variable foundation modulus.

The differential equation of the grid is then restated as a set of algebraic finite difference equations for the deflections of grid points normal to the plane of the grid. This set of equations is displayed as a single matrix equation. Card program decks or the equivalent are presumed available for the inversion of the matrix of coefficients (30 × 30 in the authors' example). F. W. Niedenfuhr, USA

1717. Klein, B., Vibration of simply supported isoceles trapezoidal flat plates, *J. acoust. Soc. Amer.* **27**, 6, 1059–1060, Nov. 1955.

Author uses method of collocation to compute approximate fundamental frequencies of isoceles trapezoidal plates with simply supported edges. Results are presented graphically for plates of different shapes. M. C. Junger, USA

1718. Mindlin, R. D., Schacknow, A., Deresiewicz, H., Flexural vibrations of rectangular plates, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-78, 7 pp.

The article deals with the influence of rotatory inertia and shear deformation on the flexural vibrations of isotropic, rectangular plates and is based partly on a previous paper by R. D. Mindlin [AMR **4**, Rev. 2826] where he shows that the three differential equations for the deflection w and the two components of rotation ψ_x and ψ_y may be uncoupled by expressing the three unknowns by three potentials. The present paper treats the solutions obtained in detail and exhibits the difference between the results obtained from this more rigorous theory and those from the classical theory of thin plates. Three examples are worked out: (1) Rectangular plate simply supported along all edges; (2) rectangular plate simply supported along two opposite edges and free along the two others; and (3) the difference between the frequency spectra in the two cases is discussed by considering the case of elastically supported edges. Two full-page frequency-diagrams for the two first cases are given.

Reviewer wishes to emphasize that the paper is written in such a way that engineers wanting practical information on the problem may profit by reading it. L. N. Persen, Norway

1719. Veletsos, A. S., and Newmark, N. M., Determination of natural frequencies of continuous plates hinged along two opposite edges, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-11, 6 pp.

Paper discusses computing of undamped natural frequencies of bending vibration of rectangular plates which are hinged along two opposite

edges and continuous over rigid supports transverse to the hinged edges. The supports divide the plate in panels. The mass per unit of the area and the flexural rigidity are considered constant in any one panel but may vary from one panel to the next.

Imagine that the plate oscillates in a steady state at an assumed frequency, the amplitude at the left-hand support having a prescribed value. Determine the amplitude of the exciting couple at the right-hand support necessary to maintain the vibration. (For the computation there is needed for each edge the constant of "dynamic flexural stiffness" and the "flexural carry-over factor," which are given in tables of Kroll, *NACA Wartime Report* L 398, 1943.) Repeat these steps for different frequencies. The desired natural frequencies are those for which the couple vanishes; they are found by interpolation. Two examples are given.
O. Bottema, Holland

1720. **Bleich, H. H., Longitudinal forced vibrations of cylindrical fuel tanks,** *Jet Propulsion* **26**, 2, 109–111 (Technical Notes), Feb. 1956.

This note is concerned with the pressure field in the fluid and the response of the wall of a cylindrical elastic tank due to small longitudinal forced vibrations. It will be seen that simple approximate expressions can be obtained, even for geometrically complicated configurations of the tank bottoms, e.g., spherical or conical bottoms.
From author's summary

1721. **Escande, L., Superposed oscillations in ordinary constant section or throttled surge tanks** (in French), *Houille blanche* **10**, (A), 283–292, May-June 1955.

The danger of superposed oscillations in surge tanks has been known for many years and is checked either by calculations or by tests on models. Using the graphical method of Calame and Gadew, the author determines for successive opening and reclosing, and for closing and reopening, the most dangerous case of surge superposition. He considers partial and total reopening, analyzes ordinary and throttled tanks, and calculates the most dangerous surge. He gives rules for determining the moment when the reverse gate movement should occur to create the most dangerous surge. In the discussions of the paper, Molbert gives some additional information on this point.
C. Jaeger, England

1722. **Lin, T. C., and Morgan, G. W., A study of axisymmetric vibrations of cylindrical shells as affected by rotatory inertia and transverse shear,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-59, 7 pp.

Authors present an analysis of the propagation of axially symmetric waves in an elastic cylindrical shell. Theory includes the effects of rotatory inertia and transverse shear in the same manner as Timoshenko's one-dimensional theory of bars. Velocities of unattenuated sinusoidal waves are computed and are compared with those obtained when rotatory inertia and shear effects are neglected. These effects are of importance for waves at high frequencies; they tend to decrease the velocity of propagation and introduce an additional mode in the phase-velocity-frequency diagram. The results presented are valid for a range in which the thickness of the shell is small with respect to the radius of the shell and to the wave length of the disturbance.
M. L. Baron, USA

1723. **Schaefer, H., Baranow's method and its extension to the determination of natural vibration modes of vibrating shafts** (in German), *Ing.-Arch.* **23**, 5, 307–313, 1955.

The so-called "Baranow method" for finding the lower natural frequency of a torsional system by first determining the highest frequency, then splitting the disks appropriately and lumping them again at the nodes of the higher mode has long been recognized as being a convenient method of surprisingly high accuracy.

The original publication is not accessible (for a description of the method see, e.g., the reviewer's paper in Ing.-Arch. 17, p. 49, 1949), hence, it was never really clear whether the method is an exact one or what approximations are involved. Author now proves that the method is an exact one indeed. Furthermore, he shows how the mode shapes of the auxiliary systems which are obtained in the process can be used for determining the natural modes of the original system.
K. Klotter, USA

1724. **Weidenhammer, F., Torsional vibrations in universally jointed shafts** (in German), *Ing.-Arch.* **23**, 3, 189–197, 1955.

Application of a universal joint for the transmission of a moment from one axis to another axis, making a small angle α with the first, has the inconvenience of introducing a small variation in the moment of the second axis, even if the driving moment of the first axis is completely constant. The resonance frequencies of the system are considered. If the natural frequency of the system for $\alpha = 0$ (elastic shaft with rotating mass at each end) is equal to ν, it appears that a number of subharmonics arise with frequencies ν/r ($r = 2,3,\ldots$). For a constant driving moment, only the resonance frequencies corresponding to even values of r occur. The resonance frequency ν is the only one which is modified by α, if α^4 is neglected.
A. I. van de Vooren, Holland

Wave Motion in Solids, Impact

(See also Revs. 1779, 2018, 2019)

1725. **Smith, P. W., Jr., Phase velocities and displacement characteristics of free waves in a thin cylindrical shell,** *J. acoust. Soc. Amer.* 27, 6, 1065–1072, Nov. 1955.

Author presents graphically the results of computations, from Kennard's equations [AMR 7, Rev. 2438], for all free waves (not just axially symmetric) with frequency as variable. Analysis is limited to wave lengths large compared with shell thickness. Paper discusses nature of waves in all regions, with analytic expressions for asymptotic cases. Motions are reinterpreted as waves traveling in helical directions on shell. Correlation of results with problem of sound transmission through shells is discussed.
M. C. Junger, USA

1726. **Mugiono, Measurements of the reflection of flexural waves at cross-sectional discontinuities of rods** (in German), *Acustica* **5**, 3, 182–186, 1955.

With the aid of solutions of the elementary bending equation, and some related experiments, author has studied the reflection of flexural waves for the cases of one and two abrupt changes of cross section in a rod. Theoretical and experimental results are in good agreement. They show for the first case that the reduction factor (a function of the energy transmitted through the changed section) increases with the ratio of section depths (larger to smaller at the change), and this increase is independent of wave length. In the second case, the reflection factor (which determines the amplitude of the reflected wave) was found to be dependent on the frequency determined by the length of rod between the two changes of section. Only moderately short waves are considered.
J. Miklowitz, USA

1727. **Volterra, E., A one-dimensional theory of wave propagation in elastic rods based on the "method of internal constraints,"** *Ing.-Arch.* **23**, 6, 410–420, 1955.

Specifying linear variation of displacements with respect to coordinates in the direction perpendicular to the axis of a slender body, author derives one-dimensional approximate equations of free flexural, torsional, and longitudinal motions from the three-dimensional theory of elasticity.

Since this procedure has been used in the past by a variety of investigators, as indicated in author's references, reviewer fails to see why author deemed it necessary to call it the "Method of internal constraints," which may be misleading, implying a high degree of novelty.

Graver, however, are a number of misconceptions which require clarification. In the case of flexural motions, author derives two different equations, both being similar to Timoshenko's and both containing the effects of transverse shear deformation and rotary inertia. Author does not account for these differences because, apparently, he is not aware of the fact that Timoshenko's theory, viewed in the light of the three-dimensional theory, neglects both components of normal stress perpendicular to the axis. Inspecting author's equations, reviewer finds, in fact, that the first (Eq. 10) is based on suppression of both components of normal strain perpendicular to the axis, while the other (Eq. 11) is based on suppression of the component of normal stress in the direction of deflection and the suppression of the component of normal strain in

the direction perpendicular to that of deflection and the axis. There are good physical reasons why Timoshenko's equations are preferable to those suggested by the author.

In the case of the torsional and longitudinal motions, author does not present any essentially new theories.

It may be advised that the reader be careful in assimilating the contents of the paper, since it is studded with wrong statements. Two examples: "The elementary theory assumes that the displacement of an element of the bar consists solely of translation perpendicular to the x axis." "Since the larger roots (of the frequency equation) do not appear to have any physical significance, they will be ignored."

G. Herrmann, USA

1728. Baron, M. L., The response of a cylindrical shell to a transverse shock wave, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954, Amer. Soc. mech. Engrs., 1955, 201–212.

Paper is a further study by similar method of problem considered by Mindlin and Bleich [AMR **7**, Rev. 33]. Analysis under review deals with oscillations, caused by impact of plane shock wave, of cylindrical shell of infinite length whose axis is parallel to wave front. Problem is thus two-dimensional, and normal modes of oscillation are as for a thin circular ring (dealt with in Appendix). These form two sets, one mainly inextensional and one mainly extensional. The contribution of the latter set to behavior of shell (not previously investigated) is principal concern of the paper.

Using an assumption which in effect requires that waves reflected and radiated by shell are approximately plane, the differential equations for amplitudes of normal modes excited are solved; the accelerations, velocities, hoop and flexural stresses, and fluid pressure are plotted and compared with previous findings.

Substantial agreement is found for the response when the shock wave has nearly enveloped the shell. In earlier stages, large fluctuations of the accelerations and hoop stress about previously published values are shown to occur.

Author concludes that long term effects are suitably represented in terms of inextensional modes only, but that the fuller treatment is essential if initial behavior of shell under impact of shock is to be adequately portrayed.

M. J. P. Musgrave, England

1729. Duvall, G. E., and Zwolinski, B. J., Entropic equations of state and their application to shock wave phenomena in solids, *J. acoust. Soc. Amer.* **27**, 6, 1054–1058, Nov. 1955.

Authors begin by summarizing the relations between the various variables at a shock front in an inviscid fluid; they then calculate the increase in entropy across the transition in terms of thermodynamic parameters. These equations are then applied, in conjunction with hydrostatic equations of state for Al, Cu, Fe, and Pb, to calculate (a) the increase in entropy across the shock front, (b) the excess pressure referred to the adiabatic pressure, and (c) the rise in temperature after relief of the shock pressure, when the solid is subjected to very high rates of stressing.

The basic assumption is that, under these conditions, the metal behaves as a fluid and its elastic properties can be described by a hydrostatic equation of state. This assumption seems to have originated with B. Hopkinson [*Phil. Trans. roy. Soc. Lond. (A)* **213**, 437, 1914] in his calculation of the stress due to the impact of a lead bullet. The assumption is confirmed by more recent work on Monroe jets [e.g., AMR **7**, Rev. 420] and by measurements on the shock front and particle velocities in metals subjected to explosive loading [AMR **8**, Rev. 3086].

R. M. Davies, Wales

Elasticity Theory

(See also Revs. 1694, 1697, 1727, 1764, 1765, 1776, 1786, 1793, 1807, 1973, 2044, 2070)

1730. Ling, C.-B., Stresses in a circular cylinder having a spherical cavity under tension, *Quart. appl. Math.* **13**, 4, 381–391, Jan. 1956.

The surface of an infinitely long cylinder under axial tension is considered to be at a finite distance from a symmetrically located spherical cavity. A biharmonic stress function is used to determine the stress at any point in the cylinder. The largest value of the ratio of the maximum stress across the minimum section of the cylinder to the mean stress across the same section is found to be 2.045.

D. Kececioglu, USA

1731. Salet, G., Singular points in two-dimensional elasticity (in French), *C. R. Acad. Sci. Paris* **242**, 4, 449–450, Jan. 1956.

1732. Hill, R., On related pairs of plane elastic states, *J. Mech. Phys. Solids* **4**, 1, 1–9, Oct. 1955.

Given a Kolossov representation of the Airy stress function ϕ as the real part of $\bar{z}f(z) + g(z)$, the hitherto discarded imaginary part ψ is shown to be (for incompressible material) a displacement function such that $u, v = \partial\psi/\partial y, -\partial\psi/\partial x$. With the state represented by (f, g) can be associated another given by $f^* = if$, $g^* = ig$. It is shown that if P, Q are components of force across a curve, $P^* = u$, $Q^* = v$; $u^* = -P$, $v^* = -Q$. Hence the associated state can be recognized through boundary conditions only. Simple correspondences are established between mean stress and rotation; principal stress differences; principal directions; resultant force on a hole and a dislocation centered in the hole. Useful results follow even if neither solution is known. Stiffness relations are deduced between incompressible elastic rectangles bonded to two rigid ends for (a) "shearing" of ends and (b) compression of ends. Kirsch's problem (hole disturbing uniform tension) transforms into rigid inclusion disturbing uniform shear. If the inclusion is subject to a central force, the transformation is to a dislocation. The analogy is an extension, for the incompressible case, of one connecting plane elasticity with slow viscous flow given by the reviewer in 1934.

J. N. Goodier, USA

1733. Dörr, J., Surface deformations and boundary forces in cylindrical rollers and bores (in German), *Stahlbau* **24**, 9, 202–206, Sept. 1955.

Approximate two-dimensional solutions are offered for the case of a cylindrical roller compressed between two parallel planes or between two very large concentric cylindrical surfaces. The well-known exact solutions for the two-dimensional cylinder or bore subjected to diametrically opposed concentrated forces are used to give an approximate solution for the deformations normal to the boundary in the neighborhood of the concentrated forces. This approximate relationship is then used, by superposition, to establish an integral equation between the loading and the deformation over the portions of the roller in contact with the loading surfaces. This integral equation is solved to obtain the loading distribution in terms of the deformation over this contact strip for a symmetrically loaded case. This solution is then applied to the symmetrical case of the cylindrical roller between two planes. It is also proposed as useful in the nonsymmetrical case of the cylindrical roller between two very large concentric cylindrical surfaces, such as the usual roller bearing.

E. J. McBride, USA

1734. Coates, R. C., A consideration of the stress analysis of ring structures, *Civ. Engng. Lond.* **50**, 594, 1359–1361, Dec. 1955.

Problem attacked is that of a horizontal circular ring mounted on a number of columns, and subject to vertical loads of various kinds. Difficulties inherent in the classical solution of the problem are pointed out, and a solution by relaxation methods is demonstrated, using unit loads and Castigliano's method. As an example, the influence line for reaction at one of four symmetrically spaced columns due to a concentrated load at various positions on the ring is worked out by relaxation methods and verified by actual experiment. Very good agreement is obtained. After external reactions are obtained, Biezeno's theorem is used to find shears, and moments, at any section of the ring. Reviewer feels that method can easily be extended to include noncircular rings, rings with noncircular cross section, and rings of variable moment of inertia.

T. A. Hunter, USA

1735. Leven, M. M., Stress gradients in grooved bars and shafts, *Proc. Soc. exp. Stress Anal.* **13**, 1, 207–213, 1955.

The stress distribution in the vicinity of notches has long been uncertain, with unexplained discrepancies between flat bars and round shafts. In this paper author shows that stress distribution for either bending, torsional, or uniform tensile stress is same for both bars and shafts when plotted in form of certain nondimensional functions based on Neuber's notch stress equations [Neuber, "Theory of notch

stresses," J. W. Edwards, Ann Arbor, Mich., 1946]. Included also are curves showing gradients of principal stresses and equivalent stress (Hencky-von Mises theory) at base of notch, as well as other stress distributions in a grooved shaft subjected to bending. C. W. Smith, USA

1736. **Sadowsky, M., Stress concentration caused by multiple punches and cracks,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-16, 5 pp.

Equivalence of punch indentation and crack problems in plane elastic media is noted. A method due to Nadai involving conjugate harmonic potential functions is used. The form of the functions is determined by mapping boundary conditions from the real plane. The problem of two punches is considered and their interaction discussed.

J. F. W. Bishop, Scotland

1737. **Magnus, H. A., Nomograph simplifies stress calculations for pressurized cylinders,** *Mach. Design* **28**, 4, 135–136, Feb. 1956.

1738. **Reissner, E., On torsion with variable twist,** *Öst. Ing.-Arch.* **9**, 2/3, 218–224, 1955.

Investigation is made of the nonuniform torsion of cylindrical shafts having a torque at one end and fixed at the other so that warping is restrained. Interest in two questions is indicated: (1) the effect of warping restraint on the relation between torque and twist; (2) the effect of warping restraint on the location of center of twist.

Approximate differential equations for torsion with restrained end warping are established by means of a variational equation for stresses and displacements, using an extension of the Saint Venant displacements which allow variation of axial displacement along the shaft.

It is shown that the effect of restraint against warping (1) decreases the angle of twist, (2) shifts the center of twist toward the centroid of the section, (3) causes the center of twist to coincide with the centroid at the fixed end, and (4) allows the center of twist to approach the center of twist obtained by the Saint Venant theory for large distance from the fixed end. M. V. Barton, USA

1739. **Wargon, A., Graphical solution for torsional problems; hydrodynamical analogy,** *J. Boston Soc. civ. Engrs.* **42**, 4, 364–373, Oct. 1955.

While torsional problems are very common in engineering, the lack of a general elementary solution becomes a very serious handicap in practical engineering. Solutions are available in the literature for particular prismatic cross sections, such as rectangular, circular, triangular, and thin-walled profiles, but no general solution for an arbitrary section is known. However, for an arbitrary section, the membrane analogy as a "model" of stresses has been found very useful. An apparatus for the measuring of the lateral deflection of the membrane is required.

Author presents a practical solution to the torsional problem, by a graphical method, which requires no special apparatus and whose degree of accuracy is, probably, of the same order of magnitude as in the soap-film membrane method. From author's summary

1740. **Nowacki, W., On certain cases of torsion of bars** (in German), *Maschinenb.-Tech.* **3**, 7, 375–382, July 1954.

Translation of AMR 8, Rev. 3351.

Experimental Stress Analysis

(See also Rev. 1777)

1741. **Frocht, M. M., and Flynn, P. D., Studies in dynamic photoelasticity,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-1, 7 pp.

By means of the so-called "streak" photography, employing a narrow slit through which a continuous stress pattern for a line element of a model is obtained in a rotating drum camera, a study is made of the propagation of stress waves in photoelastic models. With the apparatus described, exposure times equivalent to 1,500,000 pictures per second could be obtained.

Dynamic photoelastic stress patterns for a bar struck axially by a rigid mass show that a uniform state of stress was obtained. The results are in fair agreement with the theoretical values obtained by the Boussinesq solution. This means that basically the method may give useful results on application to structural problems under impact loading; to obtain quantitative values of the stress, however, the stress-optic law of model materials under dynamic loading should be further investigated. R. G. Boiten, Holland

1742. **Baud, R. V., Stresses and safety factors in bonded floor coverings subjected to swelling or shrinking** (in German), *Schweiz. Arch.* **20**, 10, 313–319, Oct. 1954.

Paper deals with the determination of the tensile and shear stresses in the bonded joint between a floor covering (parquet, tile, etc.) and base when differential swelling or shrinking occurs. Problem is treated experimentally in a photoelastic apparatus and results are related to a theoretical solution. Experimental method is simple and direct. Discussion is given of materials and control used in test. Convenient expressions are derived for the safety factor against failure in tension or shear in the bonded joint. C. F. Peck, Jr., USA

1743. **Gibson, J. E., Stress distribution under foundations,** *Engineering* **180**, 4680, 507–510, Oct. 1955.

A point load is applied centrally to an elastic beam of finite length resting upon a semi-infinite plane elastic medium with the same elastic moduli. Author proposes an approximate theoretical expression for the form of the boundary loading on the medium and develops equations for the stresses in the medium. These stresses are found by forming the integral of an Airy stress function along the boundary, differentiating under the integral sign, and then performing the integration. Photoelastic experiments using Catalin 800 models were carried out to test the adequacy of the theoretical solution, and reasonable agreement was obtained.

In addition, author describes three-dimensional photoelastic experiments on the distribution of load under an elastic plate resting on a semi-infinite elastic medium, with a central point load applied to the plate. The sandwich technique was used by making the medium of a BT61-893 plate cemented between Perspex blocks. Moderate agreement was obtained between the applied vertical load and the measured reaction boundary stresses. W. Shelson, Canada

1744. **Fried, B., and Shoup, N. H., A study in photoplasticity: the photoelastic effect in the region of large deformation in polyethylene,** *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 477–483.

Simultaneous measurements were made of stress, strain, and optical retardation in polyethylene sheet under tensile load in the linear and nonlinear stress-strain regions at various rates of strain. Strain measurements under biaxial stress were also made. Analysis of these measurements revealed that, while the relation between tensile stress and tensile strain varies with strain rate, the optical retardation in polyethylene is directly proportional to the shear strain for the strain rates of 0.02 to 0.3 in./in./min used.

In addition, the feasibility of employing photoplastic results from polyethylene to predict the strains in a geometrically similar aluminum member was studied experimentally. The fairly good agreement obtained suggests that the method has promise, but the lack of a really suitable photoplastic material remains to be overcome.

W. Shelson, Canada

1745. **Cadambe, V., and Kaul, R. K., Photoelastic determination of bending moments in curved frames,** *J. sci. indust. Res., India* **14B**, 10, 485–488, 1955.

1746. **Flanagan, J. H., Simplified calibration of photoelastic models,** *Prod. Engng. (Product Design Handbook for 1956)* **26**, 11, F26–F27, Oct. 1955.

1747. **Dally, J. W., and Durelli, A. J., Prediction of brittle coating strain sensitivity based on a statistical regression analysis,** *Proc. Soc. exp. Stress Anal.* **13**, 1, 169–180, 1955.

It has been pointed out that more than thirty variables have an influence on the strain sensitivity of Stresscoat [AMR 9, Rev. 1400 and Rev. 1748, this issue]. The operating instructions provided by the

manufacturer of Stresscoat include diagrams for the prediction of this strain sensitivity. These diagrams take into consideration three variables, namely, coating number, testing temperature, and relative humidity. However, little or no information is given concerning the influence of curing temperature and coating thickness.

In this paper, the influence of all five of the variables mentioned above has been considered. A statistical method known as "Linear regression of a multivariate universe" has been employed to obtain two equations, one for each of the two universes in which the coatings have been divided. Universe 1 includes coatings numbered 1200 to 1210, and universe 2 includes coatings numbered 1170 to 1200. By means of these equations a good prediction of the strain sensitivity of a brittle coating can be made. They also allow the operator more flexibility in the choice of the coating number by permitting him to vary the coating thickness and curing temperature as well.

From authors' summary by W. R. Osgood, USA

1748. **Durelli, A. J., Jacobson, R. H., and Okubo, S., Further studies of properties of Stresscoat,** *Proc. Soc. exp. Stress Anal.* **13**, 1, 35-58, 1955.

Continuation of report on systematic study of Stresscoat properties begun in previous paper [AMR 9, Rev. 1400]. Following 11 variables are discussed or considered in present paper: Gradient of stress in direction of coating crack, gradient of stress perpendicular to crack, elastic constants of material under coating, biaxiality of stresses, influence of hydrostatic pressure, triaxiality of stresses, second principal stress producing cracking, proximity to free boundaries, drop in temperature when load is acting on coating, effect of application of etchant, technique to etch different types of coatings.

Strain sensitivity is defined as the minimum strain necessary to crack the coating in a unidimensional state of stress (sensitivity is defined as the inverse of strain sensitivity). The strain sensitivity is determined by using a strip ¼ in. by 1 in. by 12 in. loaded as a cantilever under a constant deformation and measuring the location of the first crack. Among results found are that rise in stress gradient in direction of crack requires increased stress to crack coating; increase in stress gradient perpendicular to crack produces increase in strain sensitivity; no significant difference exists in strain sensitivity of coating on aluminum and steel strips; under biaxial state of stress, primary principal stress is governing factor and secondary principal stress is of minor importance; hydrostatic pressure to produce crazing depends on strain sensitivity of coating; in triaxial state of stress, for pressures in direction of thickness of coating from 250 to 450 psi, stress in plane of coating required for failure decreases sharply with small increases of pressure; in biaxial state of stress, when cracks produced are close together, coating between cracks is essentially in uniaxial state of stress, and much higher stress is needed to crack coating at right angles to second principal stress than the stress which produced the initial cracks; coating is thicker near free boundaries and contains more air bubbles; drop in temperature when load is acting on coating produces cracks, and strain sensitivity should be given as function of number of degrees drop in temperature and of time at the low temperature; sensitivity of coating can be increased by etching while load is on specimen or shortly after removal of load; in general, etching of old and glossy coatings is more effective than etching of fresh and dusty coatings.

Authors speculate on relation between first crack and first continuous crack observed on cantilever strip specimens.

Tests show that the Stresscoat failure phenomenon is "normal" or approximately follows Gauss' law. Statistical analysis is made of relation between decrease in strain sensitivity and heat treatment, and for interval between first crack and continuous crack, between decrease in strain sensitivity and average length of cracks, crack density, total length of cracks, and total number of cracks.

Dry-crazing in thick coating is thought to be caused by shrinkage stresses set up by more rapid drying of surface exposed to air than coating beneath surface. If temperature drops too rapidly to permit creep of coating, thermal crazing is more likely to appear when coating is on material having low coefficient of expansion.

Closing up of cracks after removal of load is discussed briefly.

Paper is followed by discussion by F. B. Stern, Jr., Magnaflux Corporation, Chicago, Ill., and by authors' closure. W. R. Osgood, USA

1749. **Radcliffe, B. M., A method for determining the elastic constants of wood by means of electric resistance strain gages,** *Forest Prod. J.* 5, 1, 77-80, Feb. 1955.

When using electric resistance strain gages on wood for the determination of elastic constants, it is important to eliminate transverse sensitivity errors introduced by the gages in the strain readings. A method is presented for computing true strain values for wood at given grain angles. E. G. Stern, USA

1750. **Majors, H., Jr., Influence of fluid pressure on SR-4 strain gages,** *Proc. Soc. exp. Stress Anal.* **13**, 1, 13-24, 1955.

Electric resistance-wire strain gages were bonded to the inside and outside surfaces of steel and aluminum tubes in the longitudinal and tangential directions, and subjected to internal oil pressures up to 6000 psi. The zero reading stability was good for gages submerged in oil at atmospheric pressures for over 200 hr. Longitudinal gages on the inside and outside of the tubes gave identical readings, whereas the inside tangential gages showed pressure effects. When several methods of compensation were used in the dummy circuit, there were varied indicated readings. Further tests are needed to show the combined effects of pressure and temperature compensation, although the experimental work indicates satisfactory results may be obtained with the dummy not subjected to fluid pressures and the active gage under pressure up to 6000 psi. From author's summary

1751. **Berger, R. A., and Brunot, A. W., Dynamic stress measurements in gas turbines,** *Proc. Soc. exp. Stress Anal.* **12**, 2, 45-54, 1955.

The study of the behavior of turbine buckets and compressor blades under operation has been and is being carried on by many investigators. The work of Schabtach and Fehr, Manson, Kemp and Morgan, Gorton, and Drew has given much valuable information on the construction and application of wire strain gages for these types of studies. As in all experimentation, however, there are new and different approaches to this problem, and this paper describes some of the experiences and methods which the authors have found most useful in their particular studies. Since the application of paper and Bakelite base SR-4 strain gages is fairly standard and since these gages cover the temperature range up to, say, 400 F, this discussion is limited to gages primarily intended for over 1000 F but usable at temperatures down to 400 F.

From authors' summary

1752. **Mark, J. W., and Goldsmith, W., Barium titanate strain gages,** *Proc. Soc. exp. Stress Anal.* **13**, 1, 139-150, 1955.

The calibration of piezoelectric barium titanate wafers for measuring dynamic tensile strains of 100 to 400 microinches per in. in the frequency range of 20 to 600 cps has been investigated. It is shown that the sensitivity of any one wafer is essentially constant, and that the sensitivities of gages of the same lot or cut from the same wafer can differ widely. A method for producing a single gage capable of measuring stress in a biaxial strain field is discussed. It was found that the calibration of a wafer may change considerably upon rebonding.

From authors' summary

1753. **Steele, N. C., and Eichberger, L. C., The use of foil gages to measure large strains under high fluid pressures,** *Proc. Soc. exp. Stress Anal.* **13**, 1, 151-160, 1955.

Results are presented for four series of experiments conducted on foil gages mounted on metal strips or plates. These experiments were undertaken to determine whether the foil gages would be suitable for the measurement of large strains while, at the same time, being subjected to high fluid pressures.

The behavior of the foil gages is encouraging.

From authors' summary

1754. **Leszynski, S. W., Strain gage applicator,** *Proc. Soc. exp. Stress Anal.* **13**, 1, 161-168, 1955.

With the advent of assembly-line production of test aircraft and guided missiles, there is a need for adequate tools and techniques to simplify the installation of strain-measurement gages. This paper deals with the description of a strain-gage applicator which provides a simple and practical tool for installing Bakelite-type strain gages on large aircraft test

structures without necessitating structure disassembly or application with improvised loading techniques, ovens, or heat lamps.

From author's summary

1755. **Skopinski, T. H., Aiken, W. S., Jr., and Huston, W. B., Calibration of strain-gage installations in aircraft structures for the measurement of flight loads,** *NACA Rep.* 1178, 29 pp., 1954.

See AMR 7, Rev. 3331

Rods, Beams, Cables, Machine Elements

(See also Revs. 1697, 1700, 1716, 1724, 1726, 1735, 1740, 1769, 1770, 1772, 1775, 1779, 1780, 1781, 1799, 1826, 1836, 1845, 2045)

1756. **Conway, H. D., The nonlinear bending of thin circular rods,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-24, 4 pp.

Author discusses bending deflection of thin vertical cantilevers initially in form of circular arc, using Bernoulli-Euler equation without simplifying assumptions on curvature. For case of single vertical load at top and that of single horizontal load at top, formal solutions are expressed in elliptic integral form. Maximum deflections in dimensionless terms are evaluated, for one value of a parameter involving load, curvature and stiffness, by a rather laborious inverse method. Results show significant deviation from linear theory only when original centerline arc subtends central angle greater than about 40°.

F. J. McCormick, USA

1757. **Kloot, N. H., Notched beams,** *CSIRO Forest Products Newsletter*, Australia 207, 1-2, June 1955.

The fact that notches in wood beams decrease their flexural resistance and not necessarily their stiffness is explained with three numerical examples.

E. G. Stern, USA

1758. **Marshall, D., Nomographs speed design of cantilever beams subjected to concentrated loads,** *Mach. Design* **28**, 2, 97-100, Jan. 1956.

1759. **Abramson, H. N., Williams, H. A., and Woolpert, B. G., An investigation of the bending of angle beams in the plastic range,** *J. aero. Sci.* **22**, 12, 818-828, Dec. 1955.

Beams of 24S-T aluminum were applied a moment with the plane of loading making various angles with the minor principal axis of the cross section. It was found that both Cozzone's method of plastic bending analysis [title source **10**, 5, 137-151, May 1943] and an analysis based on an exponential relationship between stress and strain gave reasonable correlation (within 10%) between theoretical and experimental bending moments beyond the yield strength. Rotation of the beam section, and rotation or translation of the neutral axis were neglected in both methods.

D. Kececioglu, USA

1760. **Frankland, J. M., and Roach, R. E., Strength under combined tension and bending in the plastic range,** *J. aero. Sci.* **22**, 11, 795-797 (Readers' forum), Nov. 1955.

Author confirms Barrett's comment on the analysis given in an earlier paper of the author [AMR **8**, Rev. 404] that the change in section shape has a negligible effect. Barrett's suggestion that the results of the original paper apply also for curved bars under axial compression, with eccentricities larger than one fortieth of the beam depth, is investigated and confirmed for a material with a Ramberg-Osgood parameter $n = 21$. It is found that all strain reversals occur in the elastic core of the section. Limiting values of stress are given for various values of n, based upon the criterion that a reversal of plastic strain no greater than one per cent of the elastic component of the yield strain should occur.

J. F. Besseling, Holland

1761. **Löhner, K., and Stahl, G., Calculation of a divided crankshaft held together by press fits for star engines** (in German), *Z. Flugwiss.* **3**, 3/4, 94-99, Mar./Apr. 1955.

Crankshafts for star and compound engines have to be divided. The crankpin is subjected to high stresses. The connection between crankarm and crankpin causes additional stresses, but these should not increase the stress on the pin itself. The forces and torques exerted on such crankshafts are evaluated, and it is shown that press fits may be a suitable method to transmit torques and bending moments. The pressure between ring and pin is calculated by the formulas of Saint Venant (quoted according to C. Bach, "Elastizitaet und Festigkeit" to which the authors refer as "Festigkeitslehre") and a numerical example is given. For the calculation of press fits today, more up-to-date design values are available.

P. Grodzinski, England

1762. **Cadambe, V., and Kaul, R. K., The application of membrane analogy for the determination of torsional rigidity of non-circular solid shafts,** *J. sci. indust. Res., India* **13B**, 7, 455-461, 1954.

The soap-film analogy for the determination of torsion constant K of solid noncircular shafts is described. The analogy between the bubble surface and the torsion function ϕ is clearly illustrated. The experimental technique adopted in determining the constant K consists in the measurement of the rate of increase of height h against volume, instead of direct volume measurement, by making use of the method of least squares. This procedure has compensated for the experimental errors and intermediate hanging of the film, and thus has led to greater accuracy.

From authors' summary

1763. **Roth, W., The exact solution of a loaded membrane strip under large deformation** (in German), *ZAMM* **35**, 8, 316-319, Aug. 1955.

Author considers a thin strip of length l, without bending stiffness and hinged at both ends. He assumes an initial normal force S_0. Under a lateral load q there are longitudinal and transverse displacements u and v, respectively. Assuming that q maintains its original direction and does not move longitudinally with u, author derives exact expressions for u, v, and the resulting normal force S. The formulas for v and S are very simple and easy to apply, as shown by author in two numerical examples.

M. Kuipers, Holland

1764. **Siegfried, W., Investigations into blade-root fixings of high temperature steels,** *Trans. ASME* **78**, 2, 327-338, Feb. 1956.

The progress in mechanical engineering which has led in the past few years to much lighter designs of aircraft and land vehicles can be attributed to improvements in the materials used and to a much better adaptation of structural design to these materials. In cases where the temperature is low in aircraft and land conveyances, the engineer's main problem has been alternating stresses. In applications where steels are used at high temperatures, similar problems exist, but our knowledge is here less firmly founded than in the domain of alternating stress at room temperature. The test results described, however, point to a similar line of advance as has been followed in automobile and aircraft engineering. Here, too, it is important not only to develop better materials but also to improve designs if the strength properties of these materials are to be utilized fully. It has developed that an improvement in creep properties at high temperatures can only be attained, as a rule, at the price of an increase in embrittlement and sensitivity to notching. These considerations are particularly important in the attachment of blade roots to turbine disks. A large number of tests have been made with the aim of throwing some light on these problems and obtaining a clearer idea of the basic connection between structural design and strength.

From author's summary

Plates, Disks, Shells, Membranes

(See also Revs. 1697, 1716, 1717, 1718, 1719, 1722, 1725, 1728, 1731, 1742, 1762, 1782, 1783, 1784, 1785, 1791, 1796, 1811, 1812, 1922, 1943, 2018, 2038, 2045)

Book—1765. **Kellogg Company, M. W., Design of piping systems,** 2nd ed., New York, John Wiley & Sons, Inc., 1956, xiv + 365 pp. $15.

Designers of piping systems will welcome this long awaited, much enlarged, attractive new edition of a book which has been out of print for some time. Coverage of the structural phase of piping systems is exceptionally complete; the fluid flow, fabrication and erection, and valve-design phases are not treated.

"It is the objective of this Second Edition to supplement Code rules and other readily available information with specific mechanical design approaches for entire piping systems as well as their individual components and to provide background information which will engender understanding, competent application of analytical results, and the exercise of good judgment in handling the many special situations which must be faced on critical piping. In line with this objective, the opening chapter presents a condensed treatise on the physics of materials. It is followed by a comprehensive study of the capacity of piping to carry various prescribed loadings. The utilization of materials is then considered, not only in relation to fundamental knowledge, but also on the basis of conventionally accepted practices.

"The present edition also includes a greatly augmented treatment of local flexibility and stress intensification, and a chapter on simplified methods of flexibility analysis contains several newly developed approaches which should prove helpful for general assessment of average piping, or in the planning stage of the design of critical piping. The Kellogg General Analytical Method, now extended to include all forms of loading, has been improved in presentation by the use of numerous sample calculations to illustrate application procedures, and by placing the derivations of the formulas in an appendix. Included in this edition are chapters on expansion joints and on pipe supports that offer, it is believed, the first broad treatment of these items with regard to critical piping. The rising significance of vibration, both structural and fluid, is recognized in the final chapter, which was also prepared especially for this edition. For ready accessibility of information, the charts and tables most frequently needed for reference have been grouped at the end of the text, and a detailed subject index has been provided."

Reviewer feels that the compactness of future editions would be enhanced by adopting a formal matrix notation. This would make space available for additional detail on the use of automatic computers in piping-flexibility analysis. If present trends are maintained, computers may well have completely replaced hand computation in this field by the time a 3rd edition is warranted. J. L. Lubkin, USA

1766. **Soule, J. W., The solution of multiple-branch piping-flexibility problems by tensor analysis,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-83, 5 pp.

G. Kron and others have shown how electrical networks and elastic structures can be analyzed systematically with the aid of certain tensor transformations. For a partial bibliography see B. Langefors [AMR 8, Rev. 2699]. In present paper, author shows how, in particular, to systematize the flexibility analysis of multibranch piping systems without intermediate constraints. The treatment is brief, so that considerable prior knowledge of piping-flexibility analysis, and perhaps of Kron's procedure, will be necessary before the reader can understand and apply the paper.

Among other things, author establishes well-known result that an n-anchor system leads to a system of $6(n-1)$ simultaneous equations. Reviewer feels that author should have followed this up by showing how neatly Kron's tensor methods lend themselves to the solution of several lower-order systems of equations, rather than one high-order system, at considerable savings in total computational labor. Kron, Langefors, Falkenheimer, and others have discussed this recently (see reference above). This is also discussed in the new (1956) edition of the M. W. Kellogg Company's "Design of piping systems." (See prec. review.) J. L. Lubkin, USA

1767. **Soule, J. W., Tensor-flexibility analysis of pipe-supporting systems,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-82, 4 pp.

Author extends the foregoing analysis (see preceding review) to allow for the situations arising in practical piping systems and shows how to include in the calculations the effects of pipe weight, supports, and thermal expansion. Reviewer disputes the assertion (3rd sentence) that "Hitherto this problem has been too complex to permit solution within practical time limits, except for the extremely simple cases." Such problems have been routinely treated in many engineering organizations throughout the country for years, by hand computation and by electronic computer. Reviewer agrees, however, that Kron's tensor methods may have great advantages in treating complex piping configurations. Reviewer finds disturbing the use of flexibility matrixes with infinite elements in Figs. 3 and 4; it should be possible to reformulate the equations of the system so as to avoid the need for this. When introducing the effects of pipe weight, author treats (straight) vertical and horizontal pipe sections by different methods. The intermediate case of inclined sections is not discussed, for either tangents or bends, but the procedure outlined by the author can readily be extended to these cases. J. L. Lubkin, USA

1768. **Jennings, F. B., Theories on Bourdon tubes,** *Trans. ASME* 78, 1, 55-64, Jan. 1956.

Theories of Walter Wuest; Alfred Wolf; Clark, Gilroy, and Reissner; and the author are compared. Results are presented in curves plotting the same dimensionless ratios in all cases. These curves are useful in designing Bourdon tubes of flat-oval, elliptical, or pointed-arc cross section. Experimental data are compared with a curve based on the author's simplified theory and an empirical curve of similar shape is drawn. Results of analysis of tip travel and tip force are given.

From author's summary by T. H. Lin, USA

1769. **Kafka, P. G., and Dunn, M. B., Stiffness of curved circular tubes with internal pressure,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-32, 8 pp.

Curved tubes are more flexible and attain greater stresses than straight tubes having the same cross section and subjected to the same bending moment. This effect is caused by an ovalization of the cross section of the curved tube as a result of the moment, whereas no cross-sectional deformation occurs for the straight section. A study is made of the effects of internal pressure upon these factors. The strain energy in the tube is determined as a function of internal pressure as well as for an applied moment. Results, determined by minimum energy principles, show that, for very thin-walled curved tubes, the pressure causes a large reduction in flexibility and stress factors. A tube, 3.5-in. diam, 12.5-in. turn radius, and 0.02-in. wall thickness, had its flexibility factor change from 20 to 4, and its longitudinal stress factor change from 4.5 to 1.5 by the application of 250 psi pressure. Experimental and theoretical results are in reasonable agreement.

I. Vigness, USA

1770. **Jindra, F., The thick-walled tube in plane strain with nonlinear elasticity** (in German), *Ing.-Arch.* 23, 2, 122-129, 1955.

Author treats case of thick-walled tube under internal or external pressure, a state of plane strain with nonlinear elasticity being assumed. To integrate differential equation derived, stress-strain relations are taken in following form:

$\sigma_x = 3K\epsilon_0 + 2G(1 + \gamma_2 \psi_0{}^2)(\epsilon_x - \epsilon_0)$, etc.

$\tau_{xy} = G(1 + \gamma_2 \psi_0{}^2)\psi_{xy}$, etc., where K is bulk modulus, G shear modulus, γ_2 constant, $\epsilon_0 = (\epsilon_x + \epsilon_y + \epsilon_z)/3$

$\psi_0{}^2 = 2/3\{2[(\epsilon_x - \epsilon_0)^2 + (\epsilon_y - \epsilon_0)^2 + (\epsilon_z - \epsilon_0)^2] + \psi_{xy}^2 + \psi_{yz}^2 + \psi_{zx}^2\}$

$\epsilon_x, \epsilon_y, \epsilon_z, \psi_{xy}, \psi_{yz}, \psi_{zx}$ are strain components, assumed small.

Using these relations, integration is carried out in series form; solution reduces to linear case when $\gamma_2 = 0$. Results are applied to case of cold-worked copper where $\gamma_2 = -0.18 \times 10^6$. These indicate that, for tubes made of this material and subject to internal pressure, small deviations from Hooke's law can mean relatively large reductions in peak tangential stress. Integration of differential equation using successive approximations is also discussed. A. M. Wahl, USA

1771. **Schnell, W., Load diffusion in stiffened cylindrical shells** (in German), *Z. Flugwiss.* 3, 12, 385-399, Dec. 1955.

Author deduces eighth-order differential equations describing the stress diffusion through a thin cylindrical shell stiffened by an arbitrary number of rings and stringers of different stiffnesses. Various approximations are discussed based on neglecting terms in equilibrium and stress-strain equations and on the influence of the stiffnesses; the most appropriate one can thus be chosen for a particular problem.

W. Freiberger, USA

1772. **Horvay, G., Linkous, C., and Born, J. S., Analysis of short thin axisymmetrical shells under axisymmetrical edge loading,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-3, 5 pp.

Authors attack problem of developing simple explicit formulas for

displacements, rotations, moments, and shears in short shells of varying meridional curvature and wall thickness by modification and extension of Geckeler method.

Considering the shell as an assemblage of beams on elastic foundations, authors (after Hildebrand) derive an approximate differential equation for a moderately curved tapered strip of shell that corresponds to using a one-term asymptotic expansion. For no distributed load, authors give general solution which contains four integration constants. For general prescribed edge moments and shears these constants are determined with reference to a "virtual center" cross section such that upper and lower ends of the shell are equal distances (measured along shell surface) away.

Using symmetric and antisymmetric combinations of prescribed edge moments and shears, authors derive formulas for displacements, increase in latitude angle, meridional moment, and horizontal shear force. Similar formulas are derived for prescribed edge displacements and rotations. Examples of (a) symmetrical edge shear (tensile load) and (b) antisymmetric edge shear (bending load) are given. Applications to redundant shell structures (two concentric conic shells joined by plates on top and bottom, a flanged shell with a tapered hub, etc.) are suggested.

Reviewer believes that paper presents an important application of theory to a difficult practical engineering problem.

A. P. Boresi, USA

1773. **Tschech, E., Contributions to the theory of membrane shells** (in German), *Öst. Ing.-Arch.* 9, 2/3, 224–230, 1955.

Paper deals with some general aspects of the membrane theory of thin shells. In this theory, as is well-known, the stress distribution is assumed to consist of the shear stress and the two normal stresses, all lying in the middle surface of the shell.

By taking the lines of curvature of the middle surface as curvilinear coordinates, author writes the three equations of equilibrium (two of which are differential, and the third algebraic) which govern the problem of determining the three unknown stresses. Considered, in particular, is the case of a constant internal pressure, and the explicit expressions are given for some special types of shell.

A further transformation is obtained by introducing Codazzi's equations, relating the geometrical parameters of the curvature lines. Author then writes the new equations for the case of one spherical shell and of the rotation shell.

Reviewer's remark: The problem of the membrane shells is not, in general, determined only by the conditions of equilibrium, as first demonstrated by Broglio in 1948, but also requires the employment of compatibility conditions. [See AMR 4, Rev. 1080.] P. Santini, Italy

1774. **Daners, F., Design of a one-side-open hemispherical shell; alteration of the cupola of the observatory in Vienna** (in German), *Stahlbau* 23, 8, 177–180, Aug. 1954.

Membrane shell analyses are carried out for a hemisphere with a meridional slot on one side and subjected to various kinds of loading. The results were utilized for structural design.

The approaches of W. Flügge, "Statik und Dynamik der Schalen," p. 80, and of K. Girkmann, "Flächentragwerke," were used in assuming that the edge members of the slot are loaded by the membrane forces that would exist in the continuous shell along the same lines.

Some of the mathematical derivations are not lucid, partly due to the author's notation, which was borrowed from the second reference without sufficient explanation.

F. T. Geyling, USA

1775. **Fischer, L., Design of cylindrical shells with edge beam,** *J. Amer. Concr. Inst.* 27, 4, 481–488, Dec. 1955.

1776. **Link, H., On the circular ring with limited deformation under supercritical external pressure** (in German), *Ing.-Arch.* 23, 1, 36–50, 1955.

Paper presents the problem of a thin elastic circular ring surrounded by another perfectly rigid ring, with no clearance between the two before any deformation of the elastic ring occurs. The rigid ring, however, has a much higher permeability than the elastic ring, so that external pressure may build up around the latter. The problem has its practical application in the study of the ring-like behavior of the pipe lining of a mine shaft surrounded by a thick layer of concrete. The elastic ring is assumed to be inextensional, and K. Federhorf's general solution [*Eisenbau* 12, p. 291, 1921] is used. When the external pressure exceeds a critical value, possible equilibrium configurations of the ring are found to be such that it comes in contact with the outer rigid ring at two or more equidistant points. Lower and upper bounds of the pressure intensity which determines the number of such contact points are calculated by equating, respectively, to zero the shearing force and the bending moment in the ring at the contact point. Transition from one configuration to another with the next higher number of contact points is also investigated. During the transition, a finite portion of the ring comes in contact with the outer ring, and the contact length increases with the pressure. The transition is finally completed when "Durchschlag" occurs. No experimental verification of the results is made.

Y.-Y. Yu, USA

1777. **Deutschmann, H., Model experiences with a mushroom shell** (in German), *Beton. u. Stahlbeton.* 50, 5, 148–150, May 1955.

Buckling Problems

(See also Rev. 1776)

1778. **Donnell, L. H., and Tsien, V. C., A universal column formula for load at which yielding starts,** *NACA TN* 3415, 48 pp., Oct. 1955.

Paper represents a complement to the normal column theories treating the ultimate column strength. The load which produces the first yielding of a column is computed on the basis of an idealized stress-strain diagram and is, therefore, given by an approximation only. The main value of the paper consists in the given results of an investigation of the form and size of the unavoidable defects of columns, such as deviation from straightness, accidental eccentricity of loading, lack of elastic homogeneity. It is proved from the test results that those defects are not only dependent upon the length of the column but also on the size of the section; for the yield load, the first harmonic of the deviation is of primary importance. Values of the "roughness factor" or imperfection factor are given for some cases; it is highly desirable to continue this investigation.

F. Stüssi, Switzerland

1779. **Schmitt, A. F., A method of stepwise integration in problems of impact buckling,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-37, 4 pp.

The essential difference between suggested method for finding load and deflection histories and previous solutions is that author assumes incremental loading at time intervals corresponding to the half period of compression wave cycle; other investigators have usually assumed continuous loading.

Suggested solution is compared favorably with an existing series solution given by Hoff. Author extends solution to cases in which the elastic limit is exceeded by superposing elastic solutions, each employing as effective modulus the tangent modulus corresponding to that stress level.

Reviewer believes this concept of an effective elastic modulus based on average stress does not adequately account for bending stiffness of the column; and that a more proper account of plasticity is given in *NACA TN* 3077.

J. E. Duberg, USA

1780. **De Pater, A. D. The stability of a centrally compressed bar with both finite flexure and finite shear rigidities** (in Dutch), *Ingenieur* 67, 43, 139–140, Oct. 1955.

Though the title of the paper suggests that the analysis applies to any centrally compressed bar with both finite flexure and finite shear rigidities, the paper deals only with a model of a column built up from channels connected by battens. The treatment is restricted to the case of perfectly stiff battens. This restriction is not essential, however.

Starting from the exact theory for the buckling problem of a built-up column, author shows that the method of calculation with a replacing rod, given by Engesser and Timoshenko, needs a correction which is

analogous to the correction which Haringx has given the theory developed by Biezeno and Koch, of a helical centrally compressed spring [AMR 2, Rev. 1117]. The method given in this paper satisfies the condition that its results are identical to that of the exact theory for a column with very short elements when n goes to infinity.

J. F. Besseling, Holland

1781. Friedrich, E., Additional moments in statically determinate beams due to elastic deflections (in German), *Öst. Ing.-Arch.* **9**, 2/3, 94–105, 1955.

Paper presents a method of calculating the deflections and bending moments in beam-columns. The bending moment in the beam in the absence of end loads is expanded in an infinite series, each term of which has the same form as one of the buckling modes of the beam. Only beams of uniform cross section are considered; in this case the same result can be obtained by using a Fourier series expansion. Several examples are worked out in detail.

B. A. Boley, USA

1782. Eason, G., and Shield, R. T., The influence of free ends on the load-carrying capacities of cylindrical shells, *J. Mech. Phys. Solids* **4**, 1, 17–27, Oct. 1955.

The problem of axially symmetric plastic loaded cylindrical shells has been solved by Drucker [Proc. first Midwestern Conf. Solid Mech., Univ. Of Ill., Urbana, Ill., p. 158, 1953; AMR 7, Rev. 2470]. Author extends this theory to shells of various lengths with free ends, loaded by a ring of force and a band of uniform pressure.

H. Neuber, Germany

1783. Slankard, R. C., Tests of the elastic stability of a ringstiffened cylindrical shell, model BR-4 (λ = 1.103), subjected to hydrostatic pressure, *David W. Taylor Mod. Basin Rep. no.* 876, 69 pp., Feb. 1955.

This report is part of a general experimental investigation of the elastic stability of the shell component of ring-reinforced cylinders. The over-all purpose is to obtain data for thickness-diameter ratios and to explain the discrepancy between theory and experimental results in the intermediate range of the thinness ratio λ. In particular, the model is described, experimental and theoretical strains are compared, failure of the model under external hydrostatic pressure is demonstrated by photographs and circularity parts, and the results of the test are discussed and compared with those of previous models.

The experimental buckling pressure of Model BR-4 is less than that predicted by several theories, AMR 5, Rev. 2312; AMR 7, Rev. 1762. The discrepancy is attributed mainly to the fact that the testing shell is not initially truly sound, AMR 6, Rev. 1884. However, it is not verified that the boundary conditions of experiment and theory are the same. There is good agreement between theory and experiment for curves of stress and strain.

E. A. Trabant, USA

1784. Wittrick, W. H., On the buckling of oblique plates in shear, *Aircr. Engng.* **28**, 323, 25–27, Jan. 1956.

Author presents an interesting analysis of the subject, using a finite difference method developed by M. G. Salvadori. The buckling stress depends sharply on the direction in which the edge shearing stress is applied; i.e., whether it is a positive or negative stress. The higher critical stress corresponds to the case of decreasing the oblique angle of the given parallelogram. Impressively, it may be as much as 4 or 5 times greater than the critical stress for the case of increasing the oblique angle. The computational labor for a large number of meshes in the finite difference method is emphasized.

W. H. Hoppmann, II, USA

1785. Bijlaard, P. P., Theory of plastic buckling of plates and application to simply supported plates subjected to bending or eccentric compression in their plane, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55–A–8, 8 pp.

In the first part it is shown how the principle of simultaneous loading (previously demonstrated by reviewer for a simple column) can explain the fact that deformation theory gives good results for plates and cruciform sections. Using such theory as a basis, the plastic reduction factor for eccentrically loaded plates (linearly varying stress) is worked out by strip theory and finite-difference equations. A simple approximate design formula is also developed.

F. R. Shanley, USA

Joints and Joining Methods

(See also Revs. 1701, 1824)

1786. Kuenzi, E. W., Determination of mechanical properties of adhesives for use in the design of bonded joints, *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1851, 13 pp. + 1 table, 7 figs., Jan. 1956.

Report describes test methods for determining the basic mechanical properties of adhesives subjected to shear or tension in bonds between relatively rigid adherends. The use of the properties for designing lap joints is also discussed.

From author's summary

1787. Procedures for measuring the mold resistance of protein glues, *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1344, 4 pp. + 2 tables, 2 figs., Nov. 1955.

1788. Schijve, J., Investigation on the ultrasonic testing of glued metal joints, *Nat. Luchtlab. Amsterdam Rap.* M. 1995, 25 pp. + 9 tables, 16 figs., 1955.

Tests included the measurement of energy transmission through glued joints and the examination of the natural frequencies of joints in the thickness direction. Both tests are capable of indicating regions of no bonding but give no information regarding the quality or strength of adhesive bonds. The transmission method is the superior of the two in that it permits more accurate localization of the regions of no bonding and an estimate of the thickness of the glue layer. Theoretical analyses of both methods are presented.

In reviewer's opinion, the wide scatter of the test data and the limitations of the methods suggest a dim future for ultrasonic inspection of adhesive-bonded structures.

L. Mordfin, USA

1789. Winter, H., Studies of bonding of metals (in German), *Z. Flugwiss.* **3**, 3/4, 87–99, Mar./Apr. 1955.

Report deals with experiments on the bonding of metals with "Redux" and "Araldit" and two German adhesives, which have been carried out after a study of the present technique of bonding metals abroad. The results of static and dynamic tests are given.

From author's summary

1790. Herrmann, H., Optical stress measurements in glass-metal seals at high temperature (in German), *Z. angew. Phys.* **7**, 4, 174–175, 1955.

A small cylindrical furnace with plane quartz ends is used to heat a glass-metal seal. The furnace can be mounted on a polarized microscope and the fringe patterns, caused by stresses in the glass when properly illuminated by polarized light, can be related to stresses in the glass. Seals can be studied at temperatures up to about 600 C. Equipment is described and initial results given.

I. Vigness, USA

1791. Jung, H., Calculation of the sealing effect of flanged joints (in German), *Öst. Ing.-Arch.* **9**, 4, 343–352, Nov. 1955.

Author states in the introduction to his article that theory and experiment are contradictory with regard to the question of whether the forces occurring in the bolts of a flange coupling do, or do not, change when the pressure is admitted into the pipe line. Author endeavors to elucidate this question.

C. B. Biezeno, Holland

1792. Brock, G. R., The strength of nailed joints, *Timber Technol.* **63**, 2194, 2195; 409–411, 466–469, Aug. 1955.

Results of tests on two- and three-member joints of European redwood assembled with common wire nails are presented, which confirm that stiffness and strength of nailed joints are (1) directly proportional to the specific gravity of the wood of the jointed members and (2) directly proportional to a power of the nail diameter.

E. G. Stern, USA

1793. Kihara, H., Akita, Y., Ando, N., and Yoshimoto, K., Stress studies of various shaped welded doubler in hatch corner, *Weld. J.* **34**, 10, (Weld. Res. Suppl.) 465–s–471–s, Oct. 1955.

Nine large welded ship hatch corner specimens containing welded doubler reinforcement of various shapes at the hatch corner were tested under tension for determining the most effective shape of doubler. The stress distributions were measured in both elastic and plastic states.

The shapes of doubler were circular, eccentric circular, oval, trapezoidal, and rectangular. In addition to the foregoing, a specimen of rectangular insert plate and a specimen without doubler were tested for comparison.

For all specimens, the maximum stress concentration occurred in the deck plate at the periphery of the hatch corner. The insert plate, eccentric circular, and rectangular reinforcements caused the greatest stress concentration; the circular and oval shapes resulted in intermediate values; and the trapezoidal shape yielded the least stress concentration. Local bending of the deck plate occurred near the periphery of the welded doubler for all reinforcement designs, being greater in the eccentric circular shape, and least in the insert plate.

It was concluded that the eccentric circular shape was inferior, and that the trapezoidal and oval shapes were best.

From authors' summary

Structures

(See also Revs. 1734, 1742, 1757, 1779, 1824, 1834, 1835, 1992, 2027, 2028)

1794. **Bauer, F., Approximate calculation of decrease of tension in prestressing steel wire wound on circular cylindrical shell containers** (in German), *Beton u. Stahlbeton.* **50**, 11, 287–290, Nov. 1955.

The wall of cylindrical reinforced-concrete shell containers is often reinforced by prestressing steel wire wound on it. Forces transmitted by the prestressing wire to the cylinder wall reduce the radius of the latter, whereby a reduction of tension is caused in the coils of wire already applied. The paper presents an approximate calculation of this reduction of stress.

Start is made from an intermediate phase of the winding, when it has been completed only up to a certain height. It is established what reduction Δw_1 of the radius of the cylinder mantle would take place if the winding were completed right to the end and, during this, the prestressing wire invariably preserved its initial tension. However, because of the radius reduction Δw_1, reduction of tension Δp_1 takes place in the prestressing wire at the height examined. It is supposed that a similar reduction of tension occurs in the windings of the prestressing wire above the place investigated. This modifies the value of Δw_1 previously calculated, and, accordingly, the above value of Δp_1 has to be corrected by some magnitude Δp_2. This procedure may be continued and, for the reduction of tension sought, the approximate value of $\Delta p_1 + \Delta p_2 + \ldots + \Delta p_i + \ldots$ may be obtained. Though the above approximation does not converge toward the precise solution, the rough approximation does not differ much in practical cases from the precise value, as shown by a comparative calculation executed.

The paper closes with a tabulation of formulas of ordinates of deformation and moment influence diagrams for different simple conditions of support in the calculation of infinitely long cylindrical shell containers.

P. Csonka, Hungary

1795. **Janney, J. R., Hognestad, E., and McHenry, D., Ultimate flexural strength of prestressed and conventionally reinforced concrete beams,** *J. Amer. Concr. Inst.* **27**, 6, 601–620, Feb. 1956.

Based on experimental and analytical studies of flexural behavior and ultimate strength of beams, the relative performances of various types of prestressed and conventional reinforcement are compared.

Test results of 19 rectangular beams are given, involving (1) three pretensioned, (2) three posttensioned grouted, (3) five posttensioned unbonded, (4) three posttensioned unbonded with deformed bars added, and (5) five with conventional deformed bar reinforcement. For three reinforcement percentages, the characteristics of these five types of reinforcement are compared in terms of moment-deflection relationships, deflection recovery, and ultimate strength of beams failing in flexure.

An ultimate strength analysis permitted prediction of measured ultimate moments for all beams with satisfactory accuracy.

From authors' summary

1796. **Ross, A. D., Results of experiments on beams prestressed by deformed bars,** *Civ. Engng. Lond.* **50**, 588, 639–642, June 1955.

The experiments described in this article were conducted to test the use of deformed bars for pre-tensioning and anchorless post-tensioning and to assess the performance of the resulting beams.

From author's summary

1797. **Bay, H., Oblique reinforcement of reinforced-concrete foundations over individual piles** (in German), *Beton u. Stahlbeton.* **50**, 11, 279–283, Nov. 1955.

The introductory part of paper deals with the stress state of an elastic band of shape and loading similar to the foundation to be examined. Afterwards, the shearing strength of concrete and different possibilities of failure are treated on the basis of the Mohr-Mörsch theorem. Shear tests described in Vol. 80 of *Deutscher Ausschuss f. Eisenbeton* are discussed in detail. It is established that the load-carrying capacity of the foundation stressed in shear is determined rather by the quantity of steel reinforcement crossing the cracks than by the arrangement of the reinforcement.

The final part of the paper proposes an approximate method of calculation of the pull force acting on oblique steel reinforcement of foundations. The load acting on the footing is assumed to be distributed according to a triangular diagram over the middle horizontal section of the footing. The assumed width of the diagram is equal to the height of the footing. This diagram is completed by a similar diagram line that may be drawn for reactions. The force carried by the oblique reinforcement is calculated from the section of the summarized diagram falling into the theoretical span.

The design method proposed aims at the elimination of uncertainties found in this field of practice. Its verification and motivation is, however, not convincing in the opinion of the reviewer.

P. Csonka, Hungary

1798. **Freiberger, W., Plastic flow in a beam compressed by three dies,** *Aero. Res. Labs. Melbourne, Austral.* SM Rep. no. 229, 7 pp. + 4 figs., July 1955.

The title of this report is rather misleading; it is devoted solely to finding upper and lower bounds for the collapse load of a beam deformed under plane strain conditions by three rough dies of equal width; two dies applied to one side, one die to the other side of the beam, the single die being situated between the two others. The edges of the dies are in line, and if die width is a, beam thickness is $3^{1/2}a$.

To obtain a lower bound, a modification of the well-known truncated wedge type of discontinuous stress field is used, which necessitates the beam thickness being $3^{1/2}a$. The lower bound for the pressure p on the two dies is hence found to be k (where k is the yield shear stress).

Author obtains his upper bound for the pressure on these two dies by invoking the same stress field, but replacing stress by velocity discontinuities. A lengthy computation of relative velocities leads to $3^{1/2}k$ as the upper bound. Reviewer found that a much simpler displacement mode is to assume that the single die doubly shears a section of the beam and pushes it a (small) distance δ between the two dies. If $2p$ is the pressure on the single die, external work = $2pa\delta$ (unit thickness of beam), internal dissipation of energy = $2(3^{1/2})a \cdot k \cdot \delta$. Equating these gives $p = (3^{1/2})k$.

J. M. Alexander, England

1799. **Needham, R. A., The ultimate strength of multiweb box beams in pure bending,** *J. aero. Sci.* **22**, 11, 781–786, Nov. 1955.

A method for predicting the ultimate bending strength of multiweb box beams having formed sheet metal webs is presented. Equations are derived on the assumption that the ultimate moment is reached when local crippling occurs at the junctions of the webs and the compression skin. The proposed theory is compared with 49 beams fabricated from 75S-T6 sheet and tested by the NACA. The agreement between tests and theory was extremely good.

From author's summary

1800. **Onat, E. T., On certain second-order effects in the limit design of frames,** *J. aero. Sci.* **22**, 10, 681–684, Oct. 1955.

Author investigates second-order effects in the plastic methods of design of beams and frames due to changes in geometry during plastic deformation. If these do not affect the momentum, the structure remains ideally plastic. If the momentum increases, the structure becomes unstable and collapses, as, e. g., an axially loaded column of ideally elastic material under buckling load. Author describes this effect for frames of ideally plastic and rigid strain-hardening materials, and

shows that equilibrium conditions for the latter do not become unstable.

Reviewer remarks that hinges can never behave in an ideally plastic way, not even if the material is ideally plastic; and so the danger of stability (instability) in practical cases is smaller.

G. de Kazinczy, Sweden

1801. Hognestad, E., Hanson, N. W., and McHenry, D., Concrete stress distribution in ultimate strength design, *J. Amer. Concr. Inst.* 27, 4, 455–479, Dec. 1955.

Test data are presented which demonstrate the reality and validity of the fundamental plasticity concepts involved in ultimate strength design theories such as those presented by Whitney, Jensen, and others.

A review of earlier experimental investigations regarding the stress distribution in the compression zone of structural concrete flexural members revealed that, though many test methods have been tried, very limited direct test data are available. On the other hand, considerable information has been derived indirectly from strength and behavior observed in tests of reinforced beams and columns.

An eccentrically loaded specimen and a test method were developed which permit the flexural stress distribution to be measured. Complete information regarding the flexural stress distribution, including stress-strain graphs with a descending curve beyond the maximum stress, is reported for w/c ratios of 1.0, 0.67, 0.50, 0.40, and 0.33 at test ages of 7, 14, 28, and 90 days.

From authors' summary

1802. Kenedi, R. N., Smith, W. S., and Fahmy, F. O., Light structures—research and its application to economic design, *Trans. Instn. Engrs. Shipb. Scot.* 99, 4, 207–264, 1955/56.

An analytical discussion of the experimental behavior of thin-walled struts and beams culminates in the presentation of design charts intended for direct use in the drawing office. This is followed by the description of a preliminary investigation into the behavior of "in-line" bolted joints formed in thin-gage material by 1, 2, and 3 bolts. Economic design and the derivation of optimum proportions, corresponding to maximum load carried per unit weight, for strut and beam elements are discussed in the light of "equal" and "part equal" strength sections.

The text concludes with the description of full-scale tests carried out in the field on (1) a three-hinged portal-type warehouse structure constructed entirely of cold-rolled sections and (2) a frameless oil tank roof, exemplifying the possibilities of the thin-walled type of construction when applied with ingenuity and imagination.

From authors' summary

1803. McComb, H. G. Jr., and Low, E. F., Jr., Comparison between theoretical and experimental stresses in circular semimonocoque cylinders with rectangular cutouts, *NACA TN 3544*, 20 pp., Oct. 1955.

Comparisons are made between a theory for calculating stresses about rectangular cutouts in circular cylinders of semimonocoque construction published in *NACA TN* 3200 and previously published NACA experimental data. The comparisons include stresses in the stringers and shear stresses in the center of the shear panels in the neighborhood of the cutout. The theory takes into account the bending flexibility of the rings in the structure, and this factor is found to be important in the calculation of stresses about cutouts. In general, when the ring flexibility is considered, good agreement is exhibited between the calculated and experimental results.

From authors' summary by M. C. Steele, USA

1804. Bettess, F., A graphical method for the determination of forces in arches, *Civ. Engng. Lond.* 49, 581, 1200–1202, Nov. 1954.

Article deals with a purely graphical solution for the problem of finding the forces in a two-pinned arch and also in a fixed arch. The method of attack for a two-pinned arch is to draw a trial line of thrust and then, by a graphical procedure, to determine the necessary modifications to reduce it to the true line of thrust. In the case of a fixed arch, the same method is adopted, combined with the use of characteristic points to achieve the same result.

From author's summary

1805. MacClosky, C. C., Heavy falsework loads carried by wooden bowstring trusses, *Civil Engng. N. Y.* 25, 4, 218–219, Apr. 1955.

The heaviest loads probably ever imposed on wooden bowstring trusses, 4000 lb per lin. ft, are supported by falsework for a three-span concrete arch bridge described. The actual deflection of the 180 ft long, 44-ft rise center arch amounted to 1½ in. at the crown and 1¾ in. halfway between crown and skewback.

E. G. Stern, USA

1806. Woolf, S., Structural use of timber, *Timber Technol.* 63, 2189, 2190, 2191; 121–122, 182–184, 240–242, Mar., Apr., May 1955.

The discussion of fundamental strength properties of structural wood is followed by an analysis of the various means of making structural joints: "... it seems as if nails may again become an efficient and popular fastening for fabrication of light trusses and similar constructions." Plywood I beams and stressed-skin construction, lamella roofs, laminated structures, and timber trusses are described and illustrated.

E. G. Stern, USA

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 1759, 1760, 1798, 1800, 1837, 1840)

1807. Green, A. E., Hypo-elasticity and plasticity, *Proc. roy. Soc. Lond. (A)* 234, 1196, 46–59, Jan. 1956.

Paper is concerned with stress-strain laws for a single loading followed by a partial or complete unloading of a plastic material, which is assumed to be isotropic, inviscid, and imcompressible. The laws discussed in the paper specify the rate of stress as a function of the stress and the velocity strain. Separate laws of this type are used for loading and unloading; the sign of the stress power (i.e., the scalar product of the tensors of stress and velocity strain) is used as the criterion differentiating between loading (positive stress power) and unloading. Following Handelman, Lin and Prager [*Quart. appl. Math.* 4, 397–407, 1947] the requirement is introduced that the laws for loading and unloading agree for vanishing stress power. The resulting stress-strain laws are further specialized by demanding that, in simple tension, the relation between the stress and the logarithmic strain should be linear for unloading. In addition to simple tension, the following examples are treated: simple shear, rotationally symmetric expansion of a cylindrical tube, and torsion of a circular cylinder. Except for the last problem, the solutions offered do not involve the usual neglect of inertia terms.

W. Prager, USA

1808. Lin, T. H., A proposed theory of plasticity based on slips, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 461–468.

Incremental stress-strain relations are calculated for an aggregate of randomly oriented face-centered cubic crystals. The assumptions made are similar to those of slip theory but the possible active slip directions are taken to be 60° apart in each plane for each crystal. Shear strain determines shear stress but the direction of the shear stress is taken as the bisector of the two active slip directions. Shear added to compression, therefore, results in an initial elastic response, as shown by most tests. The subsequent stress-strain curve also is in good agreement with the data. A number of simplifying assumptions are made in the numerical analysis. Reviewer believes that the approach of Sanders to stress-strain relations in the plastic range as reported in the same volume will prove more fruitful for future work.

D. C. Drucker, USA

1809. Ling, F. F., and Saibel, E., Thermal aspects of galling of dry metallic surfaces in sliding contact, Second Ann. ASME-ASLE Conf., Indianapolis, Ind., Oct. 1955. Pap. 55-LUB-4, 8 pp. + 8 figs.

Author studies theoretically, under thermal aspects, the phenomenon of galling of dry surfaces in sliding contact. These predominate when the bodies do not oscillate appreciably in the direction normal to the surfaces. (The phenomenon of galling is believed to be due to the thermal as well as mechanical conditions under which the surfaces are rubbed together.)

Author obtains a criterion for galling, expressed by a relationship involving load, velocity, and time.

A. Pignedoli, Italy

1810. **Schlechtweg, H., The problem of unloading following a plastic deformation** (in German), *ZAMM* **35**, 5, 176–183, May 1955.

This paper gives a mathematical analysis of residual stresses remaining in a work piece after plastic deformation. The analysis is couched in general terms for bodies that can be described by polar coordinates. The underlying concept of flow is comparable to a maximum shear theory of flow.

General logarithmic equations for residual stresses are derived but there has been no attempt to correlate the analytical results with test results.

R. G. Sturm, USA

1811. **Craemer, H., Plastic isotropic and orthotropic plates with full utilization of all elements** (in German), *Ing.-Arch.* **23**, 3, 151–158, 1955.

The paper is concerned with the plastic design of plates of variable thickness for minimum weight and is based on K. W. Johansen's yield condition ["Brudlinieteorier," Copenhagen, 1943] for reinforced-concrete plates. According to this, a plate element is capable of plastic deformation only when at least one of the principal bending moments reaches a critical absolute value m, which depends on the thickness of the element. Author makes the plausible assumption that minimum weight design requires that both principal bending moments attain this absolute value ("Vollausnutzung"). If conditions of loading and support are such that the principal bending moments have equal signs throughout the plate ("gleichsinnige Vollausnutzung"), the bending moment in any direction has the absolute value m, and the twisting moment vanishes. The equation of equilibrium, in conjunction with the boundary condition $m = 0$ at a simply supported edge, then determines the variation of m and, hence, that of the plate thickness. (A similar analysis based on Tresca's yield condition has recently been given by the reviewer, *Ingenieur* **67**, Nov. 1955.) If, on the other hand, the principal bending moments have unequal signs ("ungleichsinnige Vollausnutzung"), the equation of equilibrium does not specify the variation of m uniquely, unless the principal directions are known, as, for instance, in the case of rotational symmetry. Examples concerning circular, annular, and rectangular plates are presented. The examples for rectangular plates with principal bending moments of opposite signs are not convincing, because they involve arbitrary assumptions on the pattern formed by the lines indicating the principal directions. A plate design obtained from such an assumption, while adequate, is not necessarily a minimum weight design. The analysis is extended to orthotropic plates.

W. Prager, USA

1812. **Drucker, D. C., and Hopkins, H. G., Combined concentrated and distributed load on ideally-plastic circular plates,** *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 517–520.

Collapse loads for combined concentrated and uniformly distributed loadings on ideally-plastic circular plates are determined. Solutions are given for plates which overhang a simple circular support. Collapse loads for circular plates with simple or built-in end supports are obtained as limiting solutions. The Tresca yield criterion is assumed.

E. D'Appolonia, USA

1813. **Freiberger, W., and Prager, W., Plastic twisting of thick-walled ring sectors,** ASME Ann. Meet., Chicago, Ill., Nov. 13–18, 1955. Pap. 55-A-85, 3 pp., 1955.

A. J. Wang and W. Prager [AMR **9**, Rev. 130] developed a graphical method for the treatment of plastically twisted circular ring sectors with arbitrary solid cross section. This method is now extended to determine the fully plastic stress distribution in a twisted sector with a thick-walled hollow cross section, and, furthermore, to find the warping of the cross-sectional planes in the ensuing plastic flow. The ring is assumed to consist of a rigid, perfectly plastic material. Aside from the possible application to overstressed helical springs of small pitch, the solution of this problem is of interest because it illustrates the important role of discontinuities in the theory of perfectly plastic solids.

F. Chmelka, Austria

1814. **Lorsch, H. G., and Freudenthal, A. M., On mixed boundary-value problems of linear viscoelastic solids,** *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 539–545.

Deformation and stress are deduced for Maxwell bodies (dissipation depending on stress) under the following conditions: line force moving along the surface of a semi-infinite solid accompanied by uniform plane stress or uniform plane strain; strain recovery after line force is removed; plane strain accompanied by time independent stress on the surface. The latter problem is also solved for a Kelvin body (dissipation depending on rate of strain). Whereas problems in viscoelastic flow admit frequently a simple reduction to problems of elasticity, this procedure would not work in the problems considered.

The present paper constitutes an interesting contribution to theoretical rheology.

R. Eisenschitz, England

1815. **Phillips, A., and Kaechele, L., Combined stress tests in plasticity,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-15, 6 pp.

Paper covers an investigation of the combined stress-strain relations in the plastic range for an aluminum alloy 2-S-O. The tests were conducted on thin-walled tubes subjected to combined tension and torsion. The investigation covered cases of variable stress ratios. A series of tests was made in which the directions of the principle stresses were rotated while their values remained constant. The purpose of the investigation was to check the validity of the incremental theories of plasticity insofar as influence of the rotation of the principle stress axes is concerned. The results of these tests support the incremental theories of plasticity.

J. Marin, USA

1816. **Ibrahim, A. K., Equation of motion in circles about an axis for non-Newtonian liquids,** *ZAMM* **35**, 12, 463–464, Dec. 1955.

An extension of the author's previous theoretical treatment [*J. chem. Phys.* **22**, 7, 1274, July 1954]. An equation of motion is derived for the motion of a non-Newtonian fluid in circles about an axis. The equation is not solved for any examples. Error: The X in the final equation should be replaced by r.

L. Nielsen, USA

1817. **Weltmann, R. N., An evaluation of non-Newtonian flow in pipe lines,** *NACA TN* 3397, 40 pp., Feb. 1955.

Author proposes schemes for predicting pressure losses in flow of non-Newtonian fluids from measurements in concentric cylinder or capillary viscometers. For "plastic" fluids, yield value is important; structure factor for "pseudoplastics." Superior treatment for plastics is given by McMillen [*Chem. Eng. Prog.* **44**, 537–546, 1948]. Very recent paper by Metzner and Reed [*A.I.Ch.E. Journal* 434–40, Dec. 1955] is more complete for pseudoplastic fluids. In discussing nonuniform pipes and pipe transitions, author makes inconsistent statement that expected losses are higher than for Newtonians for both plastic and dilatant fluids.

I. M. Krieger, USA

1818. **Mirzadzhanzade, A. Kh., Immersion of a thin cylindrical tube into a viscous plastic fluid** (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **99**, 4, 511–514, 1954.

With reference to previous research in this field by S. M. Targ, A. A. Ilyushin, A. M. Gutkiy and A. F. Kasimov, author presents mathematical solution of the problem by establishing differential equations of the constant velocity in the horizontal position. The solution is purely mathematical.

J. J. Polivka, USA

1819. **Schultz-Grunow, F., Viscosity and the role of thermodynamics in rheological liquids** (in German), *Kolloid Z.* **141**, 3, 173–177, 1955.

Author comments on Pawlowski's and Rivlin's works on the behavior of rheological fluids.

Pawlowski, in making use of the law of thermodynamics and the Helmholtz principle, treats the dependence of viscosity on shear velocity as a problem of rheological friction law.

Rivlin, on the other hand, extends the linearity between shear stress and shear velocity, which is uniquely applicable for the Newtonian fluid, to the relation between stress tensor and velocity of deformation for the rheological fluid, and introduces there the third invariant K_3 as the complementary factor.

However, this is inconsistent with the second law of thermodynamics because the complementary factor happens to be negative, as K_3 is an odd function. Pawlowski, too, fails to attend to exclude this odd function out of his analysis.

While the Helmholtz principle holds for the Newtonian fluid only, the fact that Pawlowski succeeds in the analysis of the capillary and the

Couette streams in making use of the Helmholtz principle seems to show that he knows the pressure distributions in these streams and assumes, perhaps unconsciously, the fluids as the Newtonian ones.

After discussing in detail, author points out conclusively that it is impossible to describe physically the behavior of the non-Newtonian fluid by the use of such quantities that are valid for the Newtonian fluid only. H. Mii, Japan

Failure, Mechanics of Solid State

(See also Revs. 1729, 1736, 1799, 1810, 1828, 1838, 1839, 1843)

1820. Zaustin, M., On the danger of combined stresses in pressurized structures, *Aero. Engng. Rev.* **14,** 12, 45–48, Dec. 1955.

In this rather puzzling paper author suggests that conditions of failure and type of fracture of loaded structure may be deduced from cohesive strength s, "easily" calculated from notch tensile tests and shear fracture strength t of torsion tests on tubes. τ/σ (shear stress/normal stress) in structure and t/s of applied steel are supposed to be decisive for type of fracture. Author apparently neglects effect of full state of stress on fracture conditions. Moreover, logic fails in choice of τ, as follows from given examples (tensile test bar, pressure vessel). A number of well-known facts, which mainly have nothing to do with this vague principle, are mentioned. J. H. Palm, Holland

1821. Forscher, F., A theory of the yield point and the transition temperature of mild steel, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-42, 6 pp.

Experimental results indicate the dependence of the yield-point phenomenon of mild steel on temperature, strain rate, duration of stress, and stress state. This paper proposes a yield criterion which can account for these variables. The theory is developed on the basis of a "structural" model, by which the behavior of microscopic and submicroscopic elements is idealized. The theory postulates as yield criterion a critical number of relaxation centers (active Frank-Read sources) or, equivalently, a critical size of relaxation centers. The transition-temperature phenomenon is considered to be the result of an inhibition of yielding (upper yield point) by means of geometry, temperature, and/or strain rate. A relation is given which expresses its dependence on the state of stress and strain rate.

From author's summary by P. Bielkowicz, USA

1822. Yokobori, T., Theory of fatigue fracture, *J. phys. Soc. Japan* **10,** 5, 368–374, May 1955.

Author proposes a theory of fatigue fracture based on a reaction kinetic argument. The net forward rate of crack nucleation is obtained as the product of the equilibrium number of crack nuclei per unit volume, thermal frequency (kT/h), and a Maxwell-Boltzmann distribution in the difference between atom pair separation free energy and local (elastic) strain energy. The extension from static to cyclic loading is achieved by averaging over a half cycle. The average nucleation rate is taken to be essentially inversely proportional to time to fracture and specimen volume. The equilibrium number of crack nuclei per unit volume is expressed in terms of the number of preferred nucleation sites per unit volume by a Maxwell-Boltzmann distribution in nucleus formation free energy. The latter is obtained in terms of the stress which is also averaged over a half cycle. Finally, the portion of the equation containing stress (range) explicitly is approximated roughly by a logarithmic function leading to an S–N curve of the form

$$N = \left(\frac{-h\nu}{VZ_p kT}\right)(CS)^{-B/T}$$

where N is number of cycles to fracture, S stress range, Z_p number of preferred nucleation sites per unit volume, ν loading frequency (cps), and T is absolute temperature. C, B, b (Planck) k (Boltzmann) are constants. The author includes experimental data to which the theoretical S–N curve has been fitted and also data showing "fair" agreement with observed temperature dependence on stress (range).

A. A. Kheiralla, USA

1823. Schutte, E. H., A simplified statistical procedure for obtaining design-level fatigue curves, *Proc. ASTM* **54,** 853–864, 1954.

A testing method is suggested and statistically analyzed which appears to be very useful in tests for which testing times are long and in which considerable scatter must be expected so that the mean is not a very useful characteristic. It consists of testing groups of four specimens simultaneously until one of them fails, and discarding the rest. It is shown that the "least-of-four" results have a higher significance level than the means. A. M. Freudenthal, USA

1824. Anonymous, Static and fatigue strength of timber joints, *Bull. Amer. Rly. Engng. Assn.* **55,** 510, 213–221, Sept./Oct. 1953.

Relative static and fatigue strength data are presented for full-size bolted and grid-reinforced bolted timber joints as commonly used to fasten the sway bracing to piles and caps in timber-pile trestle construction. Repeated load tests at a rate of 60 cpm were performed at loads approximately equal to 40, 60, and 80% of the static proportional-limit loads. E. G. Stern, USA

1825. Bishop, J. F. W., On the contribution of crystallographic fibring to hardening under uniaxial straining conditions, *J. Mech. Phys. Solid* **3,** 4, 259–266, July 1955.

The effect of the development of a deformation texture in certain face-centered cubic metals on the tensile and compressive strength is examined. It is found that isotropic materials harden approximately equally in tension and compression for logarithmic strains up to 0.3. The theoretical ratio of the strengths at infinite strain is 1.13:1.

From author's summary

1826. Talbourdet, G. J., Surface endurance limits for gear and cam materials, *Prod. Engng. (Product Design Handbook for 1956),* **26,** 11, E2–E5, Oct. 1955.

1827. Peters, H., Wear in diesel engines (in Swedish), *Teknisk Tidskrift* **85,** 38, 845–850, Oct. 1955.

1828. Kazakov, N. F., Investigation of wear resistance of cutting tools by means of radioactive isotopes and radiation (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 1, 41–53, 3 plates, Jan. 1954.

Material Test Techniques

(See also Revs. 1747, 1748, 1749, 1842, 1843)

1829. Rankin, A. W., and Moriarty, C. D., Acceptance guides for ultrasonic inspection of large rotor forgings, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-194, 16 pp.

On the basis of ultrasonic inspection of 1500 rotors, reinforced by destructive and semidestructive examination (e.g., trepanning technique, magnetic particle inspection), an acceptance guide is developed by plotting in a semilogarithmic system the total number of defects over the magnitude of the sonic reflection by the defect. This pulse height is given in percentage of the reflection from the bore in a defect-free area. The ultrasonic frequency is 1 mc. The rotor forging is rotated slowly in a lathe. The reflections are divided into those coming from radial ("traveling" indications) and those from tangential defects ("stationary" reflections). In the *total number/magnitude (t.n/m)* diagram, two lines ("inner" and "outer" lines) are drawn. Forgings whose characteristics lie within the inner line are acceptable, provided that magnetic particle and visual examination reveal no harmful defect. When the *t.n/m* line lies completely between inner and outer line, four trepans are taken. Only when all defects in these trepans are nonmetallic inclusions is the rotor not rejected. If the *t.n/m* line lies outside the outer line, six trepans are taken; only low stress application is omitted. Examples are given for the application of these rules.

O. Ruediger, Germany

1830. Sinclair, D., Automatic balance for measurement of the strength of glass fibers, *Rev. sci. Instrum.* **27,** 1, 34–36, Jan. 1956.

The semiautomatic balance used to measure the tensile strength and

Young's modulus of glass fibers when bent into a loop has been made fully automatic. A differential transformer and servomotor are used to apply chain-weight as the tension in the looped fiber is increased by the loading motor.

All measurements needed to calculate the tensile strength and Young's modulus are automatically recorded on the drum chart driven by the loading motor. The maximum tensile stress in the looped fiber at the instant of break is proportional to the vertical motion of the recording pen, and the maximum strain is proportional to the rotation of the drum.

From author's summary

1831. **Mark, S. D., Jr., An apparatus for the determination of the moduli of rupture and elasticity in crossbending to 1500°C,** *Bull. Amer. ceram. Soc.* **34,** 7, 203–206, July 1955.

An apparatus is described for determining the moduli of rupture and elasticity in crossbending of small refractory specimens at temperatures to 1500 C. Methods for taking data with the apparatus are given, and a summary of the data collected during the verification of the apparatus is reported.

From author's summary

1832. **Radcliffe, B. M., and Suddarth, S. K., The notched beam shear test for wood,** *Forest Prod. J.* **5,** 2, 131–135, Apr. 1955.

Because of the existence of stress concentrations in the ASTM standard shear test specimen for wood, shear-stress values obtained with this specimen according to standard procedure are lower than the true shear values. By relieving the sharp re-entrant corner of the standard specimen with a saw-cut, stress concentrations can be reduced. On the other hand, tension-perpendicular-to-grain failure may precede shear failure. In order to obtain data on the true shear resistance of wood, use of a notched-beam test specimen is recommended. It is suggested that the present ASTM shear test be replaced with a notched-beam test.

Shear-strength values obtained and shear-stress distributions recorded with electric strain gages for the three types of test specimens are presented and evaluated.

Since many thousands of tests have been and will be performed with the ASTM standard shear-test specimen to obtain fully comparative test data, the reviewer hesitates to accept the recommendation for a change to a more elaborate testing procedure. Instead, the designer can take advantage of the information presented and make allowance for the stress-concentrations encountered in the standard test specimen. Thus, he may establish a certain factor to increase the design stress based on the standard-test stress.

E. G. Stern, USA

1833. **Baud, R. V., and Meyer, J., Magnetic testing of structural cables** (in German), *Schweiz. Arch.* **21,** 12, 404–410, Dec. 1955.

1834. **Thunell, B., Goodness estimation and nondestructive testing of constructional wood** (in Swedish), *Sven. Träforsk Inst. Medd.* **64B,** 11 pp., 1955.

Mechanical Properties of Specific Materials

(See also Revs. 1764, 1787, 1790, 1805, 1821, 1830, 1832, 1834, 1847, 1978)

Book—1835. **Rolfe, R. T., Steels for the user,** 3rd ed. rev. & enl., New York, Philosophical Library, Inc., 1956, xvi + 399. $10.00.

This book is highly practical and based on experience of the metallurgical industry. Its aim is to bridge the gap between science and practice for carbon steels in industry. The scientific aspects of the various processes are comprehensively treated, but these are illustrated by data and examples from actual service. The work deals substantially with carbon steels, and alloy steels are discussed only for duties for which carbon steels are unsuitable. This third and enlarged edition has been brought up-to-date and completely revised. From publisher's summary

1836. **Florschutz, F. E., The use of nodular iron in switchgear,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-150, 4 pp. + 7 figs.

1837. **Marin, J., and Wiseman, H. A. B., Triaxial plastic stress-strain relations for an aluminum alloy 14S-T4,** *J. Franklin Inst.* **260,** 5, 397–409, Nov. 1955.

This paper describes two types of tests on rods subjected to external radial pressure and axial tension. In one type the radial pressure and the axial tension were increased simultaneously in the same proportion. In the other type the load was applied in the same manner until a certain load was reached. Above this point the axial load was increased more rapidly than the radial pressure.

In both types of tests the strain distribution was the same as for pure tension. The results of all tests agreed well with a simple flow theory based on a plot of equivalent stress versus equivalent strain.

E. A. Davis, USA

1838. **Landers, C. B., and Hardrath, H. F., Results of axial-load fatigue tests on electropolished 2024-T3 and 7075-T6 aluminum-alloy-sheet specimens with central holes,** *NACA TN* 3631, 47 pp., Mar. 1956.

Results are presented of axial-load fatigue tests at stress ratios of 0 and −1.0 on electropolished 2024-T3 (24S-T3) and 7075-T6 (75S-T6) aluminum-alloy-sheet specimens with central holes. The specimen widths and hole diameters were varied in order to provide data suitable for a study of the effect of notch size. The data are compared with previously published results of tests on unnotched electropolished specimens and on unpolished specimens containing central holes.

From authors' summary

1839. **Grover, H. J., Hyler, W. S., Kuhn, P., Landers, C. B., and Howell, F. M., Axial-load fatigue properties of 24S-T and 75S-T aluminum alloy as determined in several laboratories,** *NACA Rep.* 1190, 25 pp., 1954.

See AMR **6,** Rev. 3745

1840. **Pugh, J. W., The tensile properties of molybdenum at elevated temperatures,** *Trans. Amer. Soc. Metals* **47,** 984–1001, 1955.

A detailed study of the tensile properties of arc-melted molybdenum in the as-swaged or annealed condition. Short-time constant-rate and creep-rupture test results between 85 and 2000 F are presented. The excellent high-temperature strength of Mo is attributed to strain aging.

N. H. Polakowski, USA

1841. **Lacy, C. E., and Keeler, J. H., Zirconium-fabrication techniques and alloy development,** *Trans. ASME* **78,** 2, 427–433, Feb. 1956.

The fabrication techniques by which zirconium and its alloys have been successfully made into various product forms are described. The neutron-absorption characteristics, mechanical properties, and corrosion resistance of zirconium and some zirconium alloys are discussed.

From authors' summary

1842. **Zhurkov, S. N., and Tomashevskiĭ, E. E., Investigation of the hardness of solid bodies II. Dependence of durability on pressure,** *Zh. tekh. Fiz.* **25,** 1, 66–73. 1955. (Translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 11 pp.)

1843. **Boller, K. H., Supplement to fatigue tests of glass-fabric-base laminates subjected to axial loading,** *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1823-A, 3 pp. + 2 figs.

See AMR **6,** Rev. 898

1844. **Boller, K. H., Effect of thickness on strength of glass-fabric-base plastic laminates,** *For. Prod. Lab. Rep., U. S. Dept. Agric.* no. 1831, 13 pp. + 12 tables, 12 figs.

1845. **Cheney, A. J., Designing with nylon, practical recommendations for engineering design of nylon parts. Part 1. Working stresses; time and environmental effects; Part 2. Dimensional control; design of** gears and bearings, *Mach. Design* **28,** 4, 5; 95–102, 95–99; Feb., Mar. 1956.

Mechanics of Forming and Cutting

(See also Revs. 1841, 1977)

1846. Rall, D. L., and Giedt, W. M., Heat transfer to and temperature distribution in a metal cutting tool, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-217, 8 pp. + 11 figs.

Authors have made a considered study of the heat transfer to a tool in a metal cutting operation. The transient temperatures in the tool were recorded, and, in the steady state, the heat flow calculated from their temperature measurements is compared with a theoretical model. The cutting tool was used as one junction of several thermocouples in a clever experimental method. Authors noticed marked changes in the temperature of the interface when the chip formation changed from discontinuous to continuous. The calibration of the thermocouples is not discussed thoroughly, and no information about the experimental uncertainty or reproducibility of data is given. R. Stevenson, USA

1847. Crane, E. V., Plastic metalworking, *Trans. ASME* **78**, 2, 413–415, Feb. 1956.

Author's "prosaic" objective is to stimulate analytical thinking, coordinate it with practice, and present it in usable form for the man in the field. The assignment is in the art and science of forcing metals to flow into new shape, as distinguished from the whittling processes of metal cutting. Exciting glimpses are caught of new possibilities in the flowing of heat-treated steels at 150 tons per square inch and more. To obtain scientific basis for the advancement of the growing art, it is necessary to pursue the relationships of plastic flow, strain hardening, aging, residual stresses, and endurance characteristics back to the space-force relationships of the atom and the molecule. Author faces the sobering responsibility that enthusiastic flights into higher mathematics, Greek leters, and coined terminologies must be brought back to a generally understandable and usable level. From author's summary

1848. Nakamura, K., Takahashi, H., and Kurihara, J., On the calculation of wire drawing force (1), The case of conventional wire drawing with work hardening, *J. mech. Lab. Japan* **1**, 1, 26–27, 1955.

1849. Nakamura, K., and Takahashi, H., On the calculation of wire drawing force (2), The case of wire drawing with back tension, *J. mech. Lab. Japan* **1**, 1, 27–28, 1955.

1850. Gary, M., The calculation of rake corrections in screw-thread measurements (in German), *Forsch. Geb. Ing.-Wes.* **21**, 4, 107–117, 1955.

Equations are derived governing the conditions of contact between spheres or circular cylinders and a screw-thread surface of general form but with straight flank profile, and resulting transcendental equations are solved by means of iteration. Rake corrections are obtained with determinable accuracy. For most convenient diameter of measuring cylinder, a relation for unsymmetrical screw threads was found. Furthermore, theory gives the contours of screw threads for an arbitrary plane of projection. General criteria are given to secure single-point contact between measuring cylinder and screw thread surfaces.
From author's summary by S. Sjöström, Sweden

1851. Kishi, M., Research on the surface treatment of zinc die-cast (2), On the method of electropolishing, *J. mech. Lab. Japan* **1**, 1, 31–32, 1955.

Hydraulics; Cavitation; Transport

(See also Revs. 1721, 1878, 1880, 1939, 1993, 2047)

1852. Plesset, M. S., and Mitchell, T. P., On the stability of the spherical shape of a vapor cavity in a liquid, *Quart. appl. Math.* **13**, 4, 419–430, Jan. 1956.

Authors study the problem of the stability of small amplitude disturbances of a spherically shaped vapor cavity during its growth or collapse in a liquid. Critical assumptions involve the neglect of the vapor density (compared with that of the liquid) and the assumption of constant internal pressure in the cavity. This latter assumption, particularly, is not valid during the final stages of collapse of a bubble, as is pointed out by the authors.

An analytical solution is found for the cavity expanding under the action of a finite pressure difference with and without surface tension (both cases are relatively stable to small disturbances) and for a bubble collapsing without surface tension under the action of a finite pressure difference (not stable). The problem of the cavity collapsing under the action of surface tension alone is also treated. The initially spherical shape is shown to be unstable in this case, too.

Authors point out that the linearized perturbation theory breaks down in the range of radii which corresponds to that for which the proposed constant pressure vapor cavity model is also invalid, i.e., during the latter stages of collapse.

The instability behavior agrees with that found previously by Birkhoff [*Quart. appl. Math* **XII**, 3, Oct. 1954; AMR **8**, Rev. 1409] by a different method; the amplitude of the surface distortions being proportional to the $(radius)^{-1/4}$ as $radius \rightarrow 0$. This behavior is essentially unaffected by surface tension. W. Daskin, USA

1853. Birkhoff, G., Stability of spherical bubbles, *Quart. appl. Math.* **13**, 4, 451–453, Jan. 1956.

An extension of a previous paper [AMR **8**, Rev. 1409] in which the perturbation equations are examined for stability. It is shown that *two* conditions are required for stability of the cavity. Author shows that the second condition (not previously discussed in the literature) corresponds to the condition that R^4A be a decreasing function, where A is defined by Eq. (3) of Plesset & Mitchell's paper (see preceding review).

This is a neat mathematical treatment of the problem. Reviewer would have appreciated some comment on the physical implication of the second stability condition. W. Daskin, USA

1854. Escande, L., Design graph for the performance of an overflowing surge tank having optimum throttling conditions (in French), *Houille blanche* **10**, special B, 671–674, Sept. 1955.

An infinitely long weir at height A above the static level and an instantaneous shut-down are considered. The optimum throttle is defined as that which produces the same overpressure Y_M at the instant of shut-down as at the instant the water reaches its highest level in the surge tank.

Two graphs have been produced, giving ω^d and the maximum overpressure (in terms of a relative value Y) as a function of p_0 and a.
From author's summary

1855. Escande, L., New hydraulic proceedings (in French), Part II, *Publ. sci. tech. Min. Air, France* no. 302, 274 pp., 1955.

This paper is a sequel to AMR 7, Rev. 1153. Twenty-three chapters assemble papers already published separately by author on such subjects as hydraulic structures, boundary layer, wakes, similitude, and—in particular—analysis of surge-tank systems. For author's earlier collections of a similar nature see AMR 2, Rev. 1152; 4, Rev. 3908
H. Rouse, USA

1856. Yih, C.-S., and Guha, C. R., Hydraulic jump in a fluid system of two layers, *Tellus* **7**, 3, 358–366, Aug. 1955.

Using the momentum principle, and neglecting shear forces, authors determine analytically the conditions downstream of a hydraulic jump, given the upstream conditions. The number of physically possible downstream states never exceeds three. If the Froude number of either the upper or lower fluid is predominantly large, the downstream state is unique.

Second half of paper investigates experimentally three particular cases: (1) upper fluid at rest; (2) lower fluid at rest; and (3) downstream velocities equal. There is fair agreement with theoretical results, especially for small jumps.

Regarding verification of uniqueness only, reviewer doubts the value of experiment. A practical demonstration of cases where downstream state is not unique would seem more interesting.
A. H. Armstrong, England

1857. Kövesi, A., Experimental measurements in model water basins (in Hungarian), *Magyar Tud. Akad. Oszt. Közl.* **15**, 1/2/3/4, 1–15, 1955.

Author determined the space of time of water leaking and emptying from reservoirs with variable sectional area, by means of theoretical calculations, and verified his calculations by the method of graphic integration on the basis of exactly deduced differential equations. Also, the results have been measured experimentally on reservoir models made according to construction drawings, controlled by chronometer with accuracy of 6/100 sec. and adjusted water flow meter. Good results have been found. In this way, author could derive suitable approximations for practice, instead of the endless calculus resulting from methods of integration. The deduced equations could profitably be utilized in projecting (practice for objects of) good use of water energy, watering plans, and other similar problems.

From author's summary by S. Apáti, Hungary

1858. **Lencastre, A., Loss of head due to bridge piers** (in Portuguese), *Lab. nacional Engen. civ. Lisboa Pub.* no. 53, 16 pp., 1954.

A survey of modern studies on the effect of bridge piers in a fixed bed channel. One-dimensional estimate of water surface and total energy lines, by Blanchet's method, is first presented. Experimental data and formulas, as well as graphical aids including coefficients to be applied and the range of reliability, are then summarized. Under the heading "Method of Koch-Carstanjen," author also summarizes a paper of G. M. Allen [*Civ. Engng., N. Y.* Mar. 1953]. In the appendix, an explanation of how to draw Joukowski symmetrical profiles for pier design is given.

Reviewer found some differences between author's conclusions and the statements of Woodward & Posey ["Steady flow in open channels, Wiley, 1941, 125–130]. Allen's method deserves some criticism: (1) It neglects pier form; (2) "kinetic momentum," as defined, is proportional to mean velocity, and statements upon the one are also statements upon the other, and, by continuity equation, upon the cross section; (3) it assumes equal depths in all sections. Escande theory ["Hydraulique Générale"–III–1943], judiciously combining Bernoulli and Euler equations and supported by experimental confirmation, is more reliable. For supercritical flow, solution would be best approached with a two-dimensional theory or by the use of models.

E. O. Macagno, Argentina

1859. **Kennison, H. F., Surge-wave velocity—concrete pressure pipe,** ASME Ann. Meet., Chicago, Ill., Nov 1955. Pap. 55—A—75, 5 pp.

Water-hammer calculations require knowledge of pressure wave velocities in the pipe material. Although these are known for steel and cast iron pipes, little is known about wave velocities in concrete pipes. Author shows variation of modulus of elasticity with pressure in several types of concrete pipes and gives tables of maximum and minimum wave velocities expected in each case. A design method is suggested based on assumed stress-strain relationship. Test results are given.

D. G. Huber, Canada

Incompressible Flow: Laminar; Viscous

(See also Revs. 1686, 1732, 1856, 1899, 1903, 1911, 1923, 1933, 1942, 1976, 1980, 1981, 1985, 2005, 2016, 2043, 2048, 2052)

1860. **Brun, R. J., Cloud-droplet ingestion in engine inlets with inlet velocity ratios of 1.0 and 0.7,** *NACA TN* 3593, 52 pp., Jan. 1956.

The trajectories of water drops approaching two different engine inlets have been calculated for a wide range of meteorological and flight conditions. The effect of inlet air velocity ratio is shown. The information in this report is of particular significance to designers of aircraft engines because the ice-free areas as well as the regions of maximum icing are clearly shown.

M. Tribus, USA

1861. **McBride, E. E., An experimental investigation of the scale relations for the impinging water spray generated by a planing surface,** *NACA TN* 3615, 42 pp., Feb. 1956.

An experimental investigation was made to determine the scale effects of the forces from water spray generated by a flat rectangular planing surface and impinging on a collector plate representative of an aerodynamic surface or other part of a water-based airplane. Lift and drag forces on the flat rectangular planing surface and on the spray-collector plate were measured. Underwater photographs of the wetted planing area and photographs of the spray generated by the planing surface were made. Two sizes of models were tested. The small model consisted of a flat rectangular planing surface with a 2-in. beam and a flat rectangular spray-collector plate 16 in. long and 10.67 in. wide. The large model was geometrically similar to the small model and was five times its linear dimensions. Tests were made with the collector plate in two vertical locations, 1.0 and 1.5 generator beams above the free water surface. The trim of the planing surface was set at 9°, 15°, and 20°, and wetted-length–beam ratios of 1.0, 1.5, 2.0, and 2.5 were tested at towing speeds from 10 to 80 fps.

The results of the investigation show that impinging-spray lift forces can be scaled by the conventional Froude relations. The small-model-spray drag forces, however, were found to be higher than those of the large model when scaled by the conventional Froude relations; thus, a Reynolds number effect on spray drag was indicated. By using an empirical method for correcting the spray friction drag coefficients on a Reynolds number basis, reasonable agreement with the Schoenherr line was generally obtained.

From author's summary

1862. **El Wakil, M. M., Priem, R. J., Brikowski, H. J., Myers, P. S., and Uyehara, O. A., Experimental and calculated temperature and mass histories of vaporizing fuel drops,** *NACA TN* 3490, 82 pp. + 28 figs, 20 refs., Jan. 1956.

Experimental and calculated mass and temperature histories of drops vaporizing with a constant velocity relative to the air velocity are compared, and it is confirmed that, under many conditions, the unsteady state or time required for the drop to reach the wet-bulb temperature is an appreciable portion of the total vaporization time. Work was done to verify or disprove the assumptions used in the computations. Data are presented to show that the assumption of infinite thermal conductivity is valid primarily because of circulation inside the drop. The presence of this circulation was verified by high-speed motion pictures. The need for a correction factor to the heat transfer to express the effect of mass transfer on heat transfer was confirmed, as well as the need for a correction factor to correct for unidirectional (as opposed to equimolal) diffusion.

Effect and extent of heat transfer down the thermocouple wires supporting the drop was evaluated; effect of large-diameter, high-conductivity wires on heat transfer was not negligible. Experimental data were taken using small-diameter wires of low conductivity. Calculations were made using different heat-transfer correlations as well as different types of averaging the properties of the film. Biggest variation was found in the value of diffusion coefficient; by using the highest computed value for the latter, the use of correlations of Ranz and Marshall produced curves agreeing reasonably well with the experimental curves. A few preliminary temperature histories of the vaporizing drops of binary mixtures were also taken, as well as a few histories of drops of different fuels vaporizing in air at sufficiently high temperatures that burning of the drops took place.

From authors' summary by K. J. DeJuhasz, Germany

1863. **Dolaptschiew, Bl., Generalization of Föppl curves in connection with vortex resistance determination** (in German), *ZAMM* **35**, 11, 427–434, Nov. 1955.

A geometrical representation is given of the simplified scheme for the solution of the problem of approximately computing the vortex resistance in the case of a circular cylinder by determining the so-called "generalized Föppl-curves." These are investigated from the points of which the vortex pairs discharge so that a symmetrical vortex street is formed, its width being approximately equal to the diameter of the cylinder. This makes possible determining the circulation and, from that, the purely theoretical application of the von Kármán resistance formula.

From author's summary by T. F. Riabokin, USA

1864. **Prakash, P., On a flow superposable on the two-dimensional radial flow,** *Ganita* **5**, 1, 21–24, June 1954.

Author shows that only a sink or source flow is self-superposable. He has also derived an irrotational flow which can be superposed on radial flow. The treatment is sketchy.

Y. V. G. Acharya, India

1865. Kadosch, M., Action of a transversal jet upon a flow (in French), *C. R. Acad. Sci. Paris* **241**, 25, 1912–1914, Dec. 1955.

Method of complex variable is applied to a lifting surface in a stream with a jet coming out of a small gap near the trailing edge, the flow in the jet being in a fixed direction in the gap and having the same total head as the rest of the fluid. Familiar methods lead to a formula for the complex velocity.

Example 1 is a flat plate edge onto the stream with a jet blowing vertically downward at the trailing edge. A circulation and lift are produced whose magnitudes are given together with other information. Moment is not given but, in fact, it can easily be shown to be zero about the center of the plate, a result surprising at first sight.

Example 2 is a jet blowing at right angles out of a wall in a stream. The jet is turned by the stream and follows a parabolic path.

One wonders what effect on the boundary layer these jets at right angles to the surface would have. J. C. Cooke, British Malaya

1866. Yen, S. M., Helander, L., and Knee, L. B., Characteristics of downward jets from a vertical discharge unit heater, *Heat. Pip. Air Condit.* 27, 11, 149–155, Nov. 1955.

Authors present axial and radial velocity and temperature traverses in free isothermal and heated downward air jets issuing from a vertical discharge unit heater using two types of outlets; a shallow diffusor and an annular outlet. This paper supplements an earlier paper by the same authors in which empirical equations were presented for calculating the down throw, jet momentum, and air horsepower of downward heated jets [AMR 8, Rev. 707].

In the present paper, authors develop further information on downward heated jets. Empirical equations are fitted to the velocity and temperature distributions along the axis of the jet. Radial velocity and temperature profiles measured at different levels below the outlet are found to be roughly similar and to approximate a normal probability curve. In isothermal jets, the rate of air entrainment into the jet per unit axial distance is known to be constant. This is borne out further by authors' measurements on an isothermal jet. In heated jets, the rate of air entrainment decreases with increasing axial distance from the outlet and eventually becomes negative. In isothermal free jets, the axial jet momentum remains constant with increasing distance downstream. In heated free downward jets, buoyancy forces decrease the downward jet momentum with increasing distance from the outlet. Authors find actual rate of decrease of jet momentum to be greater than calculated buoyancy force by up to 66% of outlet jet momentum. This discrepancy is attributed to boundary forces, i.e., friction on vertical walls, which could not be determined by the experimental techniques employed. A. W. Gessner, USA

1867. Maunoury, F., Kadosch, M., and Bertin, J., Control of jet pipe exit area by means of transverse jets (in French), *C. R. Acad. Sci. Paris* **241**, 8, 623–624, Aug. 1955.

Brief note on theoretical and experimental investigations carried out by the Societe d'Etude et de Construction de Moteurs d'Aviation in 1950 on the problem of jet-pipe exit area control by transverse jets introduced into the main stream at jet-pipe periphery.

Authors demonstrate that, if the main and auxiliary streams are joined at subsonic velocities, and if the change of direction of the latter is obtained without appreciable losses, the total thrust is the same as in the case of the main and auxiliary streams flowing separately, the auxiliary stream being bled from compressor or combustion chambers.

By using the momentum theorem for main flow and the formula presented by Bauger and Gelin for the change of momentum in the auxiliary stream, authors arrive at an equation showing that the coefficient of restriction is at minimum for the auxiliary jet flowing in opposite (180°) direction to the main stream. Experiments show, however, that minimum is obtained at an angle of 140° to the direction of flow of main stream. J. J. Dziewonski, India

1868. Craig, F. F., Jr., and Geffen, T. M., The determination of partial pressure maintenance performance by laboratory flow tests, *J. Petr. Technol.* **8**, 2, 42–49, Feb. 1956.

A method is described for predicting performance of partial pressure maintenance operations from production data obtained in laboratory gas-drive experiments. The k_g/k_0 gas-saturation relationships may be calculated if the Welge method [*Trans. AIME* **195**, p. 91, 1952] of calculating fluid saturation at the outlet faces of the cores is invoked. Although the method of calculating pressure maintenance is strictly applicable only to linear and radial systems, a step-by-step procedure is suggested for calculation of field performance of a partial pressure maintenance program. The work emphasizes that laboratory flow experiments under partial pressure maintenance conditions exhibit essentially the same flow characteristics as do laboratory flow experiments conducted under conditions of internal (solution) gas drive or external gas drive. S. R. Faris, USA

Compressible Flow, Gas Dynamics

(See also Revs. 1892, 1893, 1900, 1901, 1907, 1910, 1914, 1920, 1925, 1934, 1937, 1941, 2021)

Book—1869. Deich, M. E., Technical gas dynamics [Tekhnicheskaya Gasodinamika], Moscow, Gosudarstvennoe Energetieseskoe Izdatelstvo, 1953, 544 pp. $2.50.

Reviewer believes that while this textbook is concise and presents its subject matter with a large number of examples, the analytical rigor of the book is sacrificed for many examples and experiments which substantiate the context. Manfred Rauscher's "Introduction to aeronautical dynamics," Chapman & Hall, Ltd., London 1953, is comparable in difficulty and approach to the subject of gas dynamics. Examination of the table of contents of "Technical gas dynamics" indicates that the text is primarily intended for the use of turbine engineers in the aircraft field.

The first three chapters are devoted to the exposition of the classical equations governing one-dimensional and two-dimensional flow at constant entropy.

Chap. 4 is novel in that it treats the subject of gas flow in the presence of friction in an analytical manner. Empirical techniques are then developed for the calculation of laminar and turbulent boundary layers.

Chaps. 5 and 6 are concerned with gas discharge from nozzles and apertures. The treatment here is conventional except for the introduction and use of nomographic techniques which the reviewer believes are new. Labyrinthine compression is cursorily treated without too much development or effect. Diffusers and Laval nozzles are considered and the schlieren photographs of gas flow under varying conditions are excellent. The ejector stage is treated analytically with some experimental evidence to support the method of solution.

Chap. 7 brings forth the predominant use of nomographic techniques for studying the flow of gas through turbogenerator blades. An attempt is also made to introduce an electrohydrodynamical analog technique for the measurement of potential and velocity of flow. The amount of data presented in this chapter indicates that the author is definitely preoccupied with substantiation of analytical results and experimental data.

Chap. 8 deals with the characteristics of gas flow in the turbine stage. The techniques utilized herein are based on the mathematical expositions of the previous chapters (primarily chaps. 5 and 6).

Chap. 9 presents a method for the experimental investigation of the turbine section between the inlet and outlet valves. Reviewer believes that suggested experimental designs could be considered somewhat primitive due to their apparent inaccuracy but indicate an extremely profound comprehension of the problem. Of course, some of the suggestions for pressure measurement are presently in use or already obsolete. The use of optical interferometry in the study of flow patterns is commendable but not necessarily practical.

Generally speaking, reviewer believes that the textbook is a good treatment of applied turbine-engineering theory. Several original theorems are presented without derivation so they cannot be examined for validity. Reviewer further believes that chaps. 5 through 9 (inclusive) are worthy of further exposition and study by aeronautical engineers and power-plant designers and suggests that some attempt be made to translate these portions of the text. N. M. Matusewicz, USA

1870. Ackeret, J., Drag caused by gasdynamical relaxation (in German), *Z. Flugwiss.* **4**, 1/2, 14–17, Jan./Feb. 1956.

In multiatomic molecules, several degrees of freedom may show relaxation; i.e., they may lag if the state is rapidly changed. For example, the CO_2 molecule, which is linear with C in the center, requires an average of 5×10^4 shocks for excitation of its transversal vibration, whereas only few shocks are necessary for translation and rotation excitation. Kantrowitz has shown that relaxation results in entropy increase and this, according to a theorem by Oswatitsch, leads to additional drag. Using the Kantrowitz energy-relaxation law, author has performed the calculations for the linearized subsonic flow of CO_2 along a wavy wall, showing thereby that relaxation drag may reach values of the same order of magnitude as friction drag.

P. Schwaar, France

1871. **Küssner, H. G., Critical remarks on three-dimensional airfoil theory in subsonic flow** (in German), *Z. Flugwiss.* **4**, 1/2, 21-26, Jan./Feb. 1956.

Author's general method for solving problems in unsteady lifting-surface theory [AMR 7, Rev. 3640] is applied to the case of incompressible flow past an elliptic wing of infinite aspect ratio, with bilinear downwash distribution. Expressions for the lift and moment are obtained and compared with known approximate results.

A. R. Mitchell, Scotland

1872. **Fradenburgh, E. A., and Wyatt, D. D., Theoretical performance characteristics of sharp-lip inlets at subsonic speeds,** *NACA Rep.* 1193, 8 pp., 1954.

See AMR 7, Rev. 893.

1873. **Griffith, W. C., Interaction of a shock wave with a thermal boundary layer,** *J. aero. Sci.* **23**, 1, 16-22, 66, Jan. 1956.

A plane shock wave sweeping over a heated surface will encounter a thermal layer which disturbs the foot of the shock and thereby modifies the pressure distribution along the surface. This problem has been experimentally investigated in the shock tube. The thermal layer has been generated by a hot steel plate slid into the test section just before the tube has been fired. A theory has been developed for those cases in which the shock is sufficiently strong and the heating small enough for the shock to extend clear to the surface. This theory has been tested for shock pressure ratios up to 1.36 and surface temperatures up to 80C. The observed shape of the shock and pressure distribution along the surface agree well with predictions. When the speed of sound at the surface exceeds the shock velocity, pressure disturbances propagate ahead of the main wave, and the total pressure rise extends over about two heated thicknesses.

J. Rotta, Germany

1874. **Bowman, J. E., and Niblett, G. B. F., The passage of a plane shock wave through a wire gauze,** *Proc. phys. Soc. Lond.* **68**, part 12, 432B, 1008-1016, 1955.

The head-on collision of a plane shock (pressure ratio of 1.65) with a wire gage (20 mesh, 50% solidity) in a 2-in. × 8-in. shock tube is described. Some interesting shadowgraphs of this type of interaction are presented.

The theoretical and experimental work is rather limited by comparison with that reported in the following references:

"Some comments on 'A theoretical and experimental study of shock tube flows'," by D. S. Dosonjh, *J. aero. Sci.* 22, 11, 797-798, Nov. 1955 (AMR 9, Rev. 1220); "Head-on collision of plane shocks with wire screens," by J. W. Franks, *Univ. Toronto. Inst. Aerophys. Tech. Note* (to be published).

I. I. Glass, Canada

1875. **Romig, M. F., The normal shock properties for air in dissociation equilibrium,** *J. aero. Sci.* **23**, 2, 185-186 (Readers' Forum), Feb. 1956.

1876. **D'iakov, S. P., Interaction of shock waves with tangential and slight breaks** (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **99**, 6, 921-923, 1954.

Author merely lists the possible configurations arising from interactions between shock waves, contact surfaces, and weak disturbances in the case of two-dimensional steady flow.

F. J. Berry, England

1877. **Keune, F., The influence of compressibility at and around Mach number one for slender bodies and rotational bodies** (in German), *Z. Flugwiss.* **4**, 1/2, 47-53, Jan./Feb. 1956.

A generalization of the method of Oswatitsch and Keune for flows around bodies of revolution near Mach number one is given. An approximation of the nonlinear part of the gas dynamical equations shows an influence of compressibility near and at Mach number one, which depends on the velocity gradient at sonic speed on the body. Through the area rule, the theories are valid both for slender wings and bodies of revolution.

From author's summary by R. C. Roberts, USA

1878. **Bömelburg, H. J., Comment on "wedge pressure coefficients in transonic flow by hydraulic analogy,"** *J. aero. Sci.* 22, 10, 731-732, Oct. 1955.

1879. **Mangler, K. W., Calculation of the pressure distribution over a wing at sonic speeds,** *Aero. Res. Counc. Lond. Rep. Mem.* 2888, 42 pp. + 3 tables, 22 figs., 1955.

Method is given for calculating pressure distribution and aerodynamic forces and moments on a wing (1) at incidence, (2) in steady roll, and (3) in steady pitch. It is assumed that the flow is inviscid with no vorticity outside the wake and that incidence and thickness ratios are small. The method is based on slender-wing theory and the results are valid if $|1-M^2|A^2 \ll 1$, i.e., either for any Mach number M for wings of small aspect ratio A, or for any aspect ratio for sonic speeds.

The main features of the pressure, sidewash, and downwash fields around a flat wing at $M=1$ are clearly set out, showing the different physical conditions applying to flow (1) forward of any point of the trailing edge and (2) aft of the maximum span of the wing. In this last region there is no load for a wing at constant incidence or in steady roll.

The method is applied to determine the lift curve slope, the pitching-moment coefficient, and the stability derivatives l_p, z_q, and m_q for a family of wings in terms of aspect ratio A, taper ratio λ, and sweep ratio a. Results are given in the form of charts for a wide range of planforms.

The pressure distribution at sonic speed is given for (1) a straight tapered swept wing and (2) a similar wing with a faired shape. It is shown that the planform with curved edges without corners has a much smoother pressure distribution. In a real flow it is likely that a rounded leading edge produces a smoother chordwise pressure distribution, possibly without a great increase in drag. A similar fairing of the trailing edge near the center of the wing would produce a more even pressure distribution over that area also.

It is believed that the present calculations show the main trends of the behavior of a wing at sonic speeds, but that second-order terms may be required to allow for thickness effects.

Many features of the method are similar to that given by Mirels [*NACA TN* 3105]. However, the present report gives numerical results for a much wider range of planforms.

A. W. Babister, Scotland

1880. **Bryant, R. A. A., The transonic flow hydraulic analogy,** *J. aero. Sci.* **23**, 1, 90-91, Jan. 1956.

1881. **Trilling, L., and Covert, E. E., Quasi-steady nonlinear pitching oscillations in transonic flight,** *J. aero. Sci.* 22, 9, 617-627, Sept. 1955.

Problem is to estimate nonlinear pitch-ups in transonic swept wing aircraft, pitch-ups resulting from tip-stall, and shock-wave effect on pressure distribution. These phenomena produce several extrema of the pitching-moment variation with angle of attack, which is represented as a cubic. Equations are derived for the airplane longitudinal oscillation. Two approximate methods are worked out to solve the initial displacement problem: namely, for small damping, the exact solution of the undamped motion equation is used as the first step of an iteration procedure; and, for appreciable damping, the exact solution of the equation with critical damping and a special nonlinearity serves as a basis for calculations. Two typical aircraft serve as numerical examples to illustrate the methods. Beside defining the general nature of the aircraft motion, the method is particularly useful in investigating the variation of damping, undisturbed attitude, and other flight parameters, analytically.

J. De Young, USA

1882. Diaz, J. B., and Ludford, G. S. S., A transonic approximation, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 651–658.

That pressure-density relation is determined which best fits that of a polytropic gas near the sonic point but which retains the analytical simplicity of the Tricomi gas. The (p, ρ) relation of the gas that exactly satisfies Tricomi's equation has second-order contact in the sonic point with that of the polytropic gas. In order to obtain (p, ρ) relations which have higher-order contact, Tricomi's equation is generalized to

$$u_{yy} - y\,u_{xx} - f(y)\,u = 0$$

The function $f(y)$ is determined so that solutions of the same type as for Tricomi's equation, viz.,

$$u = A(y)\,B(\zeta), \quad \zeta = -\xi\eta = (4/9)\,y^3 - x^2$$

where ξ and η are the characteristic variables, exist. The (p, ρ) relations corresponding to $f(y)$ contain a number of parameters. These are determined so that third-order contact with the (p, ρ) relation of the polytropic gas occurs in the sonic point. In the subsonic region, the obtained (p, ρ) relation deviates from that of the polytropic gas, but one of the parameters still can be determined in such a way that the approximation is good in the supersonic region. For this choice the general solution of the partial differential equation for the stream function can be expressed in terms of Bessel functions.

A. I. van de Vooren, Holland

1883. Oliver, R. E., An experimental investigation of flow about simple blunt bodies at a nominal Mach number of 5.8, *J. aero. Sci.* 23, 2, 177–179 (Readers' Forum), Feb. 1956.

An experimental investigation was conducted in the GALCIT Hypersonic Wind Tunnel to determine flow characteristics for a series of blunt bodies at a nominal Mach number of 5.8 and free-stream Reynolds numbers per in. of 0.6×10^5, 1.2×10^5, and 2.4×10^5. The measured values for the pressure coefficient distributions are compared with a modified Newtonian expression. The agreement is very good for the three-dimensional bodies and is fair for the circular cylinder transverse to the free-stream flow direction. A complete report of the investigation is given in a GALCIT Hypersonic Wind Tunnel Memorandum.

From author's summary

1884. Zysin, V. A., Zysina-Molozhen, L. M., Poliakov, K. S., and Shapiro, I. G., Interferometric investigation of the flow around cascades of turbine profiles by trans- and supersonic flows (in Russian), *Teploenergetika* 2, 2, 38–43, 1955 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 12 pp.).

1885. Lidov, N. L., Theory of linearized solutions for nearly one-dimensional self-analogous gas flow (in Russian), *Doklady Akad. Nauk SSSR* (N. S.) 102, 6, 1089–1092, 1955.

Author states that generally the characteristics of unsteady adiabatic flow of an ideal gas depend on three essentially constant parameters a, b, and Σ, and that, further, (without restriction on generality) one can always take the dimensions of these parameters in the form:

$$[a] = ML^k T^s, \ [b] = L^m T^n, \ [\Sigma] = T^{-l}$$

Using spherical coordinates, author then introduces dimensionless velocity components $\tilde{V}_r$, $\tilde{V}_\theta$, $\tilde{V}_\varphi$, pressure $\tilde{P}$, and density $\tilde{R}$ as follows:

$$V_r = b^{1/m}\, t^{-(n/m)-1}\, \tilde{V}_r(\lambda, \nu, \theta, \varphi);$$

$$V_\theta = b^{1/m}\, t^{-(n/m)-1}\, \tilde{V}_\theta(\lambda, \nu, \theta, \varphi);$$

$$V_\varphi = b^{1/m}\, t^{-(n/m)-1}\, \tilde{V}_\varphi(\lambda, \nu, \theta, \varphi);$$

$$P = a\, b^{-(k+1)/m}\, t^{(n/m)(k+1)-(s+2)}\, \tilde{P}(\lambda, \nu, \theta, \varphi);$$

$$\rho = a\, b^{-(k+3)/m}\, t^{(n/m)(k+3)-s}\, R(\lambda, \nu, \theta, \varphi)$$

where $\lambda = br^{-m}\, t^{-n}$ and $\nu = \Sigma t^l$

Author then expands these five dimensionless parameters in a power series in ν. It is presupposed that the first terms in the expansion correspond to a "self-analogous" flow with spherical symmetry. The next terms in the five series then satisfy five linear partial differential equations (λ, θ, φ are the independent variables) with variable coefficients. Various relations are derived between the zeroth and first-order terms in the series.

J. H. Huth, USA

1886. Lidov, N. L., Finite integral equations related to the one-dimensional self-analogous adiabatic motion of gases (in Russian), *Doklady Akad. Nauk SSSR (N. S.)* 103, 1, 35–36, 1955.

Author starts with the usual nonlinear equations of flow for one-dimensional adiabatic motion of a perfect gas. (Gravity is taken into account only for the case of flow with spherical symmetry.) Attention is then focused on a special class of flows (self-analogous) for which the problem can be reduced to finding four functions of a single parameter λ. ($\lambda \sim r^{-m}\, t^{-n}$.) Author then claims to find new integrals of the resulting four simultaneous ordinary differential equations in λ. Little explanation is given; reader is presumed to be familiar with the book: "Methods of similitude and dimensionality in mechanics," by L. I. Sedov.

J. H. Huth, USA

1887. Kalishevich, I. Z., Solution of boundary-value problems in supersonic gas flow without shocks (in Russian), *Doklady Akad. Nauk SSSR* (N. S.) 102, 6, 1085–1088, 1955.

Author uses characteristic coordinates and a functional approach to treat four problems in supersonic gas flow. (1) Flow is given along an arc AB. Motion is determined in a closed domain bounded by AB and characteristic segments emanating from points A and B. (2) Hydrodynamic flow parameters are given on characteristic segments AB and BC. (Each segment is taken from a different family of characteristics.) The given parameters are consistent at point B. Motion is determined in a closed domain bounded by AB and BC, and two other characteristic segments emanating from the ends A and C. (3) Motion is determined in a closed domain bounded by a characteristic segment AB, on which hydrodynamic parameters are known; a free surface AC with given constant pressure; and a characteristic segment of the other family emanating from point B. (4) Motion is determined in a closed domain bounded by a characteristic segment AB on which the flow parameters are given; a rigid wall AC; and a characteristic segment BC of the other family.

J. H. Huth, USA

1888. Van Dyke, M. D., A study of hypersonic small-disturbance theory, *NACA Rep.* 1194, 21 pp., 1954.

See AMR 7, Rev. 3951.

1889. Connors, J. F., and Meyer, R. C., Design criteria for axisymmetric and two-dimensional supersonic inlets and exits, *NACA TN* 3589, 42 pp., Jan. 1956.

For Mach numbers up to 4.0, design charts are presented for single and double-oblique shock inlets and for isentropic axisymmetric and two-dimensional surfaces having theoretically focused Mach lines. Nondimensional geometric contours with corresponding local Mach number and flow-angle variations are presented for a systematic family of isentropic surfaces for Mach numbers from 2.0 to 4.0 in increments of 0.25. All solutions are carried from the free-stream Mach number to a local Mach number of unity and are applicable for use in the design of either inlets or exhaust nozzles.

For isentropic inlet applications there exists a compression limit based on a theoretical analysis of shock structures having a single wave intersection at the cowl lip and satisfying the condition of equal pressures and flow direction on either side of the vortex sheet. Shock solutions corresponding to this limit are demonstrated by the use of pressure-deflection polars. At a free-stream Mach number of 4.0 an all-external-compression inlet with focused compression at the cowl lip is thus limited to a theoretical total-pressure recovery of 0.685, determined solely by shock losses.

The requirement of both internally and externally attached shocks at the cowl lip is also considered. For isentropic inlets, this consideration is less restrictive with regard to maximum total-pressure recovery than the limit based on shock structure.

A comparison was then made of the performance of the isentropic inlet designed on the basis of the shock-structure compression limit and the theoretical optimum performance of single- and double-oblique shock configurations for free-stream Mach numbers up to 4.0.

From authors' summary

1890. Schrenk, O., A simple approximative method for the calculation of the wave resistance of supersonic diffusers (in German), *Z. Flugwiss.* 3, 11, 361–370, Nov. 1955.

Paper presents a very rapid method of predicting the wave drag of supersonic diffusers with and without conical spikes. The method is based on inviscid considerations only and is admittedly crude, but claims correct relative results for different geometries and Mach numbers. Comparison of this approximation with exact solutions by means of characteristics, or controlled experimental data, is lacking. It is

stated that about two hours are required to calculate a drag coefficient once the system has been set up.

Derivation of method is presented in detail. Two linearized solutions due to Lighthill [*Aero. Res. Counc. Lond. Rep. Mem.* 2003, 1945 and *J. Mech. appl. Math.* 1, p. 76, 1948 and an additional linear solution for the case of conical spikes are combined with a corrective function. The correction is obtained by comparing the exact calculations for a specific contour with the linear solutions. The solution is then applied as an approximation to other contours representing a straight diffuser or a curved one. H. P. Liepmann, USA

Wave Motion in Fluids

(see also Rev. 2019)

Turbulence, Boundary Layer, etc.

(See also Revs. 1873, 1903, 1982, 1984, 1986, 1987, 1997, 2000, 2053)

1891. **Korkegi, R. H., Transition studies and skin-friction measurements on an insulated flat plate at a Mach number of 5.8,** *J. aero. Sci.* 23, 2, 97–107, 192, Feb. 1956.

The main theme of this paper is the delayed transition at Mach number 5.8 resulting from an apparently increased stability of the laminar boundary layer at this Mach number over that at lower Mach numbers. The more extensive observations of the persistence of laminar flow on a flat plate to high Reynolds numbers, the insensitivity to roughness elements, and the smaller angle of transverse contamination (as previously noted by Nogamatsu, title source 22, 3, Mar. 1955) are of considerable interest and importance. While reasons for these effects are not established, the author's discussion is thought provoking. Measurements reported herein of skin friction in the laminar, transitional, and turbulent regions, together with profiles of density, temperature, velocity, and Mach number, are noteworthy contributions to the growing fund of information on boundary layers at high Mach numbers.

The reader will find this a highly informative paper.

G. B. Schubauer, USA

1892. **Moeckel, W. E., Some effects of bluntness on boundary-layer transition and heat transfer at supersonic speeds,** *NACA TN* 3653, 43 pp., Mar. 1956.

Large downstream movements of transition observed when the leading edge of a hollow cylinder or a flat plate is slightly blunted are explained in terms of the reduction in Reynolds number at the outer edge of the boundary layer due to the detached shock wave. The magnitude of this reduction is computed for cones and wedges for Mach numbers to 20. Concurrent changes in "outer-edge" Mach number and temperature are found to be in the direction that would increase the stability of the laminar boundary layer.

The hypothesis is made that transition Reynolds number is substantially unchanged when a sharp leading edge or tip is blunted. This hypothesis leads to the conclusion that the downstream movement of transition is inversely proportional to the ratio of surface Reynolds number with blunted tip or leading edge to surface Reynolds number with sharp tip or leading edge. This conclusion is in good agreement with the hollow-cylinder result at Mach 3.1.

Application of this hypothesis to other Mach numbers yields the result that blunting the tip of slender cones or the leading edge of thin wedges should produce downstream movements of transition by factors ranging from 2 at Mach 3.0 to 30 at Mach 15. The significance of this result is discussed with regard to the possible reduction in over-all heat-transfer rate and friction drag for aircraft flying at high supersonic speeds.

Mach number profiles near the surfaces of blunted cones and wedges are computed for an assumed shape of the detached shock wave at flight Mach numbers to 20. The dissipation and stability of these profiles are discussed, and a method is described for estimating the amount of blunting required to produce the maximum possible downstream movement of transition. From author's summary

1893. **Brinich, P. F., Effect of leading-edge geometry on boundary-layer transition at Mach 3.1,** *NACA TN* 3659, 44 pp., Mar. 1956.

The effect of leading-edge geometry on transition position, recovery-factor distribution, boundary-layer profile, and the roughness required to induce transition has been investigated at Mach 3.1 for a hollow cylinder aligned with the air stream. The effect of surface-heat conductivity on the recovery-temperature distribution was also studied.

A large downstream displacement of the transition point and an increase in recovery factor were noted when a sharp leading edge was very slightly blunted. These effects were attributed to the formation of an inviscid shear layer near the surface caused by the curvature of the leading-edge shock. The boundary layer thus develops in a region of lower Mach number existing within this shock-produced shear layer. The delay in transition is predominantly an effect of a Reynolds number reduction within the reduced velocity region of the inviscid shear layer. A still larger downstream displacement of the transition point was observed for an externally beveled leading edge. This effect is only partly explained by the Reynolds number reduction within the inviscid shear layer caused by the leading-edge oblique shock.

A study of the effect of single roughness elements on transition showed that slight increases in leading-edge bluntness increased the roughness required to induce transition when transition was relatively far from the element. When transition was nearer the element, the behavior was reversed.

Studies of surface-temperature distributions on models having various surface-heat conductivities indicated that surface-heat-conduction effects could only partially account for the premature temperature rise ahead of the transition point. From author's summary

1894. **Yen, K. T., Approximate solutions of the incompressible laminar boundary-layer equations for a flat plate in a shear flow,** *J. aero. Sci.* 22, 10, 728–730, Oct. 1955.

The two-dimensional steady boundary-layer problem for a flat plate in a shear flow of incompressible fluid is considered. Solutions for the boundary-layer thickness, skin friction, and the velocity distribution in the boundary-layer are obtained by the Karman-Polhausen technique. Comparison with the boundary layer of a uniform flow has also been made to show the effect of vorticity. From author's summary

1895. **Schrenk, O., A simple derivation of the momentum theorem of the boundary-layer theory** (in German), *Z. Flugwiss.* 4, 1/2, 27–28, Jan./Feb. 1956.

This is a brief paper, presenting merely a new derivation, somewhat simpler than is given in previous literature, for the well-known equation for the relation between momentum in any boundary layer, the pressure gradient (along the surface), and the shear stress at the surface. The contribution is therefore a pedagogical one; the equation obtained by the new derivation is completely equivalent to the widely known equation originally derived by von Karman [*ZAMM* 1, p. 233, 1921; *NACA TM* 1092]. R. H. Norris, USA

1896. **Schuh, H., On determining boundary-layer separation in incompressible flow,** *J. aero. Sci.* 22, 5, 343–345 (Reader's Forum), May 1955.

Author extends his semiempirical method to compressibility. The result is given in a graph which shows the pressure increase to separation in relation to the Mach number. It should give at least a lower limit for the critical pressure rise. The investigation refers to steps, wedges, and shocks in the two-dimensional flow.

F. Schultz-Grunow, Germany

1897. **Wundt, H., Growth of the laminar boundary layer on a cylinder with oblique flow** (in German), *Ing.-Arch.* 23, 3, 212–230, 1955.

Author treats the special case of three-dimensional incompressible nonstationary boundary-layer flow in which the system of boundary-layer differential equations breaks up into a partial system for two velocity components and into an equation for the third one. This special case occurs for oblique flow round an infinite cylinder. Under the assumption that the time dependence of the potential flow outside the boundary layer is of the form

$$\vec{V}(x,y,z;t) \begin{cases} = 0 & \text{for } t < 0 \\ = \vec{\mathfrak{Z}}(x,y,z)\cdot t^n & \text{for } t \geqslant 0 \end{cases}$$

author transforms the system of partial differential equations for the

boundary layer into a system of ordinary linear differential equations by means of Blasius' "time series." In the case $n = 0$, explicit expressions for some first coefficients are given.

Results are applied to the growth of laminar boundary layer in oblique flow round an infinite cylinder of circular cross section. The time and point of separation of laminar boundary layer is also given in this case.

J. Polasek, Czechoslovakia

1898. Szablewski, W., Turbulent flow in divergent channels (in German), *Ing.-Arch.* **22**, 4, 268-281, 1954.

Using Prandtl mixing-length assumption to relate turbulent shear stress to mean velocity, author analyzes flow in a two-dimensional channel of small divergence (less than 5°). As a first approximation, the velocity gradient terms in the boundary-layer equations are neglected and velocity distributions are derived for regions close to and far from the wall. These are variations of the well-known logarithmic and wall laws. Comparison is made of the derived laws to the results of Nikuradse [*VDI-Forshungsheft* 289, 1929]. Trend of curves is in agreement, but numerical results are not. A second approximation is obtained by combining the mixing-length assumption with a modified momentum equation. The resulting integral equation is linearized to obtain an explicit solution. Good agreement is found between the second approximation and experimental results.

In spite of verification of the theoretical laws by the experiments, reviewer does not think paper makes a substantial contribution to boundary-layer theory. Mixing-length distribution is arbitrary and has no fundamental importance. Recent advances in the analysis of boundary layers under pressure gradient should eliminate the need for analyses such as are presented in this paper. W. D. Baines, Canada

1899. Chiu, W.-C., and Rib, L. N., The rate of dissipation of energy and the energy spectrum in a low-speed turbulent jet, *Trans. Amer. geophys. Un.* **37**, 1, 13-26, Feb. 1956.

Paper reports a study of the correlation coefficients between eddy velocity components measured at two different points in space, the energy spectrum, and the rate of dissipation of energy in a low-speed turbulent jet. The result of this study shows that the local isotropy proposed by Kolmogoroff prevails. It also gives the order of magnitude of the mean rate of dissipation of energy. From authors' summary

1900. Mager, A., On the model of the free, shock-separated, turbulent boundary layer, *J. aero. Sci.* **23**, 2, 181-184 (Readers' Forum), Feb. 1956.

By free shock-separated boundary layers, one means that type of separation where the flow downstream of the separation region is free to adjust to any direction that may result from the shock-boundary-layer interaction process. A detailed model of the free shock-separated turbulent boundary layer is postulated, and the pressure rise following from this model is estimated and compared with experiments. The results are applied to the prediction of separation in an overexpanded nozzle. From the author's summary by S. I. Pai, USA

1901. Li, T. Y., Simple shear flow past a flat plate in a compressible viscous flow *J. aero. Sci.* **22**, 10, 724-725 (Reader's forum), Oct. 1955.

By transformation of variables, the problem of a simple shear flow of a compressible fluid over a flat plate is reduced to the corresponding problem for an incompressible fluid. The Prandtl number of the compressible fluid is assumed to be unity and its viscosity to be a linear function of temperature. T. Y. Toong, USA

1902. Cooper, R. D., and Tulin, M. P., Turbulence measurements with the hot-wire anemometer, *AGARDograph* no. 12, 58 pp., Aug. 1955.

Authors briefly review significant turbulence parameters and their measurement using hot-wire anemometry techniques. A summary table is given which lists significant experimental hot-wire investigations, including the parameters measured in each. Paper also includes comprehensive bibliography, a brief review of basic circuitry, and a discussion of sources of error. Reviewer highly recommends this work as an excellent guide to those proposing to conduct turbulence research.

M. S. Macovsky, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 1863, 1865, 1870, 1871, 1879, 1893, 1918, 1919, 1921, 1934, 1938, 2034, 2035, 2036, 2037, 2055)

1903. Riegels, F. W., New results of airfoil theory (in German), *Z. Flugwiss.* **4**, 1/2, 57-63, Jan./Feb. 1956.

A summary of the work at Göttingen over the past two years on special subjects of applied theoretical aerodynamics is given. It deals with the treatment of the first and the second fundamental problems of airfoil theory, the improvement of the procedure of calculation of laminar and turbulent boundary layers, the use of program-controlled computing machines in cases of aerodynamic problems, and the presentation of a two-parametric law of similarity for subsonic and supersonic flow.

From author's summary

1904. Kainer, J. H., Equations for the loading, section pitching-moment coefficient, and center-of-pressure distributions on triangular wings having supersonic leading and trailing edges for various basic camber distributions, *J. aero. Sci.* **23**, 2, 137-145, Feb. 1956.

Graphs presented permit evaluation of linearized-theory values of subject aerodynamic quantities for wings which are a segment of a two-dimensional fourth-order cylindrical surface. G. E. Nitzberg, USA

1905. Zlotnick, M., Aerodynamic cross-coupling between side force and normal force on bodies and wing-body combinations, *J. aero. Sci.* **23**, 2, p. 192 (Readers' Forum), Feb. 1956.

1906. Söhne, W., Directional stability of towed airplanes, *NACA TM* 1401, 53 pp., Jan. 1956. (Translation of: "Die Seitenstabilität eines geschleppten Flugzeuges," *Ing.-Arch.* **21**, 4, 1953.)

See AMR 7, Rev. 1906.

1907. Kainer, J. H., Spanwise variation in the pitching-moment coefficient and the center of pressure due to various basic twist distributions on triangular wings having supersonic leading and trailing edges, *J. aero. Sci.* **22**, 9, 598-606, Sept. 1955.

Aim of present paper is to proportion loadings obtained in a previous paper [AMR **7**, Rev. 881] to the control points of the structural matrix. Design charts and generalized formulas are presented for spanwise distribution of center of pressure and pitching moment coefficient corresponding to constant, linear, quadratic, and cubic twist distributions for several values of the leading edge Mach number parameter $\beta \tan \epsilon$. The solutions are valid for all supersonic values of the trailing edge Mach number parameter.

Graphs are given for spanwise distribution of load, pitching moment coefficient, center of pressure, and bending moment coefficient for a 45° delta wing at $M = 1.6$ and 10° incidence with (1) no washout and (2) 5° linear washout.

Results are applicable directly to rigid wings and may be used for aeroelastic problems by superposition or by the method of AMR **5**, Rev. 846. S. Kirkby, England

1908. Draper, C. S., Flight Control, *J. roy. aero. Soc.* **59**, 535, 451-477, July 1955.

Paper develops a description of what the author considers to be the principal contribution of the Wright brothers to the development of the airplane. Shortcomings of the efforts of earlier investigators are pointed out. It is the author's primary premise that the Wright brothers intentionally designed their airplane to be inherently unstable and depended upon the human pilot to introduce stability to the over-all system of airplane plus pilot. He states that this concept was the basic contribution made by the Wright brothers to start the age of flight, whereas others had failed due to a universally accepted dogma that aircraft should be inherently so stable that the human pilot would only have to steer the vehicle while playing no part in its stabilization. The author then goes on to describe the evolution of automatic flight controls in the United States.

Author's conclusions are thought-provoking and are certain to promote much discussion among those having an interest in the history of the development of the airplane. This is particularly true since he relegates the Wrights' contributions to lateral control, airframe con-

struction, propellers, engines, and wind-tunnel experimental techniques (all of which they contributed to in substantial measure) to a comparatively secondary rank.

It appears that author defines an airplane as being "inherently unstable" if it fails to exhibit positive stability which is quantitatively at least as great as a suggested "acceptable stability," which is quite high by normal standards. This somewhat unorthodox definition of "inherent stability" may be largely responsible for his conclusion that the intentional creation of an aerodynamically unstable aircraft was the key element to man's first successful airplane. W. O. Breuhaus, USA

1909. **Campbell, J. P., and McKinney, M. O., Jr., A study of the problem of designing airplanes with satisfactory inherent damping of the Dutch roll oscillation,** *NACA Rep.* 1199, 18 pp., 1954.

See AMR **7**, Rev. 1214.

1910. **Katzoff, S., Faison, M. F., and Dubose, H. C., Determination of mean camber surfaces for wings having uniform chordwise loading and arbitrary spanwise loading in subsonic flow,** *NACA Rep.* 1176, 17 pp., 1954.

See AMR **6**, Rev. 3828.

1911. **Reed, W. H., III, An analytical study of the effect of airplane wake on the lateral dispersion of aerial sprays,** *NACA Rep.* 1196, 16 pp., 1954.

See AMR **7**, Rev. 2250.

1912. **Castles, W., Jr., and Leeuw, J. H. D., The normal component of the induced velocity in the vicinity of a lifting rotor and some examples of its application,** *NACA Rep.* 1184, 15 pp., 1954.

See AMR **6**, Rev. 3172.

1913. **Eppler, R., Laminar profiles for gliders** (in German), *Z. Flugwiss.* **3**, 10, 345-353, Oct. 1955.

Two series of airfoil profiles are presented which can be considered as modifications of the NACA series 6 airfoils. These airfoils are claimed to be especially useful in the low Reynolds number regime associated with wings of gliders. Furthermore, the pressure distribution is chosen such that a cambered section will produce a low drag effect near a lift coefficient of 1.0 (desired for turning flight), and also near low values of the lift coefficient appropriate for straight, high-speed flight. Tabular and graphical data are given for the coordinates and local velocities of these profiles with thickness ratios of 6, 9, 12, 15, and 21%. H. P. Liepman, USA

1914. **Sacks, A. H., Vortex interference on slender airplanes,** *NACA TN* 3525, 19 pp., Nov. 1955.

This interesting note gives the basic theory for the calculation of those interference forces on slender wing-tail-body combinations which arise from the vorticity shed from the wing, particularly in cases where the trailing-vortex sheet has rolled up into trailing line vortexes. Such interference forces in steady flight are shown to depend on the impulses of each shed vortex evaluated at the trailing edge of the wing and the base section. As an illustration, the effect of a rolled-up vortex on a tailplane is calculated for a body in steady flight.

G. N. Ward, England

1915. **Ginzel, G. I., Theory of the broad-bladed propeller,** *Aero. Res. Counc. Lond. curr. Pap.* 208, 34 pp. + 9 pp. Addendum, 50 figs., 1955.

Paper presents three-dimensional analysis of the downwash, downwash derivative, and shock-free entry flow for propeller blades which cannot be validly analyzed by the lifting-line theory. Result is given as a correction factor. Influence of camber, number of blades, and circulation distribution is shown.

Reviewer believes aerodynamicists of propeller companies have incorporated similar analysis in modern propeller design for some time and that little novelty exists in current treatment. J. B. Duke, USA

1916. **Amer, K. B., and Gessow, A., Charts for estimating tail-rotor contribution to helicopter directional stability and control in low-speed flight,** *NACA Rep.* 1216, 22 pp., 1955.

See **AMR 8**, Rev. 191.

1917. **Guderley, K. G., The flat plate with an angle of attack in a choked wind tunnel,** *J. aero. Sci.* **22**, 12, 844-866, Dec. 1955.

The purpose of this paper is to calculate the pressure distribution on a flat plate in a choked wind tunnel. The problem is solved using the linearized transonic potential flow equations in the velocity (hodograph) plane. The results of this calculation show that the pressure coefficient on a plate in a choked wind tunnel is surprisingly near that in free flight for a plate whose chord is one tenth the wind-tunnel height and at an angle of attack of 5.7°. The practical result that can be obtained from this analysis is an estimate of the effective Mach number and angle of attack for a model tested at high subsonic Mach numbers in closed wind tunnels.

This paper will undoubtedly be of interest to the mathematically minded aerodynamicist, as well as to others who can appreciate the application of some of the fine points of analysis. E. E. Covert, USA

Aeroelasticity (Flutter, Divergence, etc.)

(See also Rev. 2038)

1918. **Laidlaw, W. R., and Halfman, R. L., Experimental pressure distributions on oscillating low aspect ratio wings,** *J. aero. Sci.* **23**, 2, 117-124, 176, Feb. 1956.

The distribution of lifting pressure over the surface of low aspect ratio wings oscillating in an incompressible flow has been measured. Rectangular, sweptback, and delta planforms were tested as well as a wing-tip tank configuration. Measurements were made both in the wind tunnel and in still air. The pressures were determined by means of a small lightweight barium titanate pressure transducer while the wings performed simple harmonic pitching and vertical translation motions. The pressures so obtained were then integrated numerically to yield lift and pitching-moment distributions and total lift and pitching-moment coefficients. Wherever possible, the final results were compared with theoretical aerodynamic data. The results have led to a number of conclusions regarding the relative status of existing lifting-surface theories.

From the authors' summary by I. E. Garrick, USA

1919. **Molyneux, W. G., Measurement of the aerodynamic forces on oscillating airfoils,** *Aircr. Engng.* **28**, 323, 2-10, Jan. 1956.

The various techniques for oscillatory force measurements are considered in relation to their application to the measurement of the aerodynamic coefficients for a rectangular wing oscillating in modes of vertical translation and uniform pitch. It is shown that the eight relevant coefficients are obtainable by any of the techniques described.

The survey is not exhaustive, but it provides a basis for comparison of the various techniques and should be of assistance to investigators in this field in indicating the particular technique most likely to meet their requirements. From author's summary

1920. **Van Dyke, M. D., Supersonic flow past oscillating airfoils including nonlinear thickness effects,** *NACA Rep.* 1183, 17 pp., 1954.

See AMR **7**, Rev. 1185.

1921. **Amer, K. B., and Hirsch, H., Effect of high advancing-tip Mach number on helicopter blade flapping,** *J. aero. Sci.* **22**, 7, 505-506, July 1955.

1922. **Eisley, J. G., The flutter of simply supported rectangular plates in a supersonic flow,** *Cal. Inst. Technol. Guggenheim Aero. Lab.* OSR-TN-55-236, 43 pp. + 12 figs., July 1955.

Paper studies flutter of a simply supported rectangular plate in supersonic flow. Only small plate deflections are allowed and aerodynamic theory is linear. Flutter mode is described by a series expansion in terms of normal modes in a vacuum. (Author calls this "exact.") In one case, result is simplified by using strip theory. For a second simplification, air forces are taken in a quasi-steady form, i.e., air forces are linearized in terms of reduced frequency. Theoretical comparisons are made. Using strip theory, flutter boundaries are computed for plates of varying aspect ratio. Mach numbers considered are $(2)^{1/2}$ and 2.

Y. L. Luke, USA

1923. Kemp, N. H., and Sears, W. R., On the wake energy of moving cascades, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-33, 7 pp.

The rate of transfer of energy to the vortex-wake pattern is calculated for isolated thin airfoils and cascades of thin airfoils in unsteady flow. This part of the work parallels earlier investigations by Garrick and Keller. Application is made to the elementary two-row stages treated in an investigation of the induction effects due to relative motion of the blade rows. The results show that the energy transferred to the wake pattern is a small fraction of the work absorbed by the rotor. Cross-induced contributions for a two-row stage may be negative but are small. By far the greatest contribution to the wake energy is that due to the circulation fluctuations induced in a blade row by the relative motion of the adjacent downstream row.

From authors' summary by J. R. Schnittger, Sweden

1924. Ozker, M. S., and Smith, J. O., Factors influencing the dynamic behavior of tall stacks under the action of wind, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-69, 6 pp.

Tall stacks vibrate under the action of steady winds. The direction of this vibratory motion is normal to wind direction. The stack structure under wind action constitutes a self-excited vibrational system. Vibration frequency is the natural frequency of the structure and remains constant for all wind velocities. The stack is at resonance at all times. There is no critical wind velocity in the sense of forced vibrational response. The amplitudes increase with increasing wind velocities.

All other structural features being the same, brick-lined, riveted steel stacks possess more structural damping than gunite-lined welded steel stacks. Structural damping of self-supporting gunite-lined welded steel stacks is predominantly through the foundation. The logarithmic decrement for the latter type is essentially constant for sizable deflections.

The logarithmic decrement for building-supported, brick-lined, riveted steel stacks increases with increasing amplitudes. In conventional stack arrangements, steam generators when present underneath the stack appear to serve as vibration absorbers, thereby contributing substantially to the over-all damping capacity.

Specific information presented in this paper on damping in various types of stack structures can be used to advantage in the design of stacks having essentially the same features.

From authors' summary by S. Odman, Sweden

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 1710, 1751, 1827, 1869, 1954, 1955, 1958, 1959, 1984, 1997, 2002, 2004, 2006, 2008, 2033, 2034, 2035, 2040, 2041, 2042)

Book—1925. Smith, G. G., Gas turbines and jet propulsion, 6th ed., New York, Philosophical Library, Inc.; London, Iliffe & Sons Ltd., 1955, 412 pp. $15.

The first edition of Geoffrey Smith's book on "Gas turbines and jet propulsion" appeared late in 1942 at a time when the subject had an aura of newness and sensation. Much of the real information had to be withheld, and it was not until the fourth edition in 1946 that the field was opened to inspection by the public at large.

The fifth edition appeared in 1950, a year before the death of Mr. Smith, and in that edition the scope of the book was enlarged considerably, giving more attention to contemporary detail practice.

This book has served in a modest way to record the major milestones in an important new field. The sixth edition, edited by F. C. Sheffield, follows the plan of the fifth edition but has been somewhat enlarged and systematized, enhancing clarity of presentation, but perhaps subduing, to some extent, the personal touch of Geoffrey Smith which characterized the earlier editions. Even though he may not have intended it to serve as a periodic survey of progress in this art, the book has come to play a welcome role in this respect.

Like earlier editions, this latest book presents factual data with few embellishments in the way of interpretation. There is thus very little in this edition of a fundamental nature which is new and original.

The major additions in comparison with previous editions have been made in chaps. 10 to 12 inclusive, covering the present status of aircraft gas turbines all over the world. The last chapter in this series, chap. 12, contains information on recent European developments which is certain to be of interest to American readers.

Chap. 13, on "Compounded units," presents an interesting discussion on the problem of compensating for the shortcomings of the piston engine in aircraft propulsion. The comparison with turbojets and turboprops is interesting, even though no conclusion is made as to the ultimate future of the compound engine.

Chap. 14, on "Ramjets, pulsejets and rockets," and chap. 15, on "Rotating wing propulsion," have likewise been expanded considerably, even though this material is of necessity incomplete.

Chap. 16, on "Turbines for road vehicles," and chap. 17, on "Other turbine applications," give much interesting information, particularly on developments in the automotive field. On the whole, however, they give testimony to the fact that only one field has been truly revolutionized so far by the gas turbine; this is the aircraft field, to which the book is mainly devoted.

C. R. Soderberg, USA

1926. Soo, S. L., and Morain, W. A., Some design aspects of the free-piston gas-generator-turbine plant. Part I. Thermodynamics and component characteristics, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-146, 30 pp. + 4 tables, 37 figs.

Design aspects of free-piston gas-generator-turbine plants are presented, including: Practical consideration of the effects of valve pressure drops, heat-exchanger effectiveness, cooling, combustion, and component efficiencies in the analysis of simple or compound cycles; comparison of cycles using thermodynamic charts, taking into account the foregoing effects; component arrangements, and characteristics of pulsating flow through a turbine.

From authors' summary

1927. Morain, W. A., and Soo, S. L., Some design aspects of the free-piston gas-generator-turbine plant. Part II. Controls and accessories, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-155, 20 pp. + 11 figs.

The various aspects of the control of free-piston gas-generator-turbine plants are discussed and analyzed. Operation with multiple-gas generators is treated, together with the over-all plant control. The accessory requirements and instrumentation problems are presented. A few design comments are given to assist those contemplating the design of free-piston machinery.

From authors' summary

1928. Light, F. H., A planned turbine testing program, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-53, 10 pp.

Book—1929. Fuchslocher, and Schulz, H., Pumps [Die Pumpen], 9th ed. of book by Matthiessen and Fuchslocher, Berlin, Springer-Verlag, 1955, vii + 188 pp. DM 16.50.

This book is confined to pumps for incompressible media, namely liquids. The treatment is elementary, the theoretical part sometimes inaccurate.

First part, about two-thirds of book, is devoted to rotating (turbo) pumps of radial and axial types. Only one-dimensional theory is dealt with for radial pumps, while single airfoil theory is applied for axial pumps. Description of mechanical details takes up about one half of this part, including those of rotary piston type, where again material on design methods and mechanical details is well-balanced. The third part on ejector pumps contains merely a few descriptive pages.

As a whole, the book is readable and may be recommended to those who want a rapid glance of the performance of different pump types.

L. S. Dzung, Switzerland

1930. McCormack, W. J., Performance characteristics of Francis-type pump-turbines, *Trans. ASME* **78**, 2, 417-426, Feb. 1956.

The object of this paper is to bring to the attention of operating companies and consulting engineers some general hydraulic characteristics of developed Francis-type pump-turbines in order to assist them in designing and evaluating proposed installations. Complete performance and cavitation characteristics are presented, together with an illustrative example showing how to select the optimum unit for a given set of operating conditions.

From author's summary

1931. **Wilson, W. A., Santalo, M. A., and Oelrich, J. A., A theory of fluid-dynamic mechanism of regenerative pumps,** *Trans. ASME* 77, 8, 1303-1316, Nov. 1955.

A hypothesis which treats a regenerative pump impeller as a centrifugal device has been shown to be consistent with the observed performance of commercial pumps. Qualitatively, the derived relations satisfy the major details of the observed flow phenomenon. It is remarkable that only three performance parameters are necessary to describe the performance of a hydrodynamic unit throughout its complete range of operation.

The correlation with the work of Busemann shows that the regenerative pump impeller performs like other centrifugal units. Radial clearance beyond the impeller tip is the major geometrical feature modifying the theoretical slip factor determined by Busemann.

One of the important irreversibilities associated with the circulatory flow can be evaluated as a Spannhacke "shock loss." Additional turbulent-type losses proportional to the square of the circulatory flow have been related to the casing geometry for the particular rotor tested. The losses associated directly with through-flow are found to be due principally to turbulent losses in inlet and outlet.

From authors' summary by W. B. Palijenko, Canada

1932. **Revuz, J., Families of profiles of blades of axial compressors** (in French), *Rech. aéro.* no. 37, 11-16, Jan./Feb. 1954.

Author applies the method of the electric analogy, according to the procedure indicated by Legendre and Malavard, for the determination of families of wing profiles for axial compressor blades. In the plane of the hodograph there is fixed the contour λ which defines the law of variation of the velocity magnitude on varying its inclination along the profile: for a given λ, three parameters can be arbitrarily chosen, corresponding to the Mach number to the infinite upstream, the angle of attack of the velocity to the infinite upstream on the axis of the cascade of profiles, and the deviation of the velocity produced by said cascade. By the analog method, the field in the plane of the hodograph is calculated, and by the usual integration method the coordinates of the profile contour in the physical plane are obtained. The results for ten profiles corresponding to three families of wing profiles are subsequently given.

C. Ferrari, Italy

1933. **Valdenazzi, G. L., The calculation of the bladed diffusers for centrifugal compressors** (in Italian), *Aerotecnica* 35, 5, 267-277, Oct. 1955.

Flow and Flight Test Techniques

(See also Revs. 1755, 1768, 1861, 1891, 1915, 1917, 1957, 2069)

1934. **Nelson, W. H., Allen, E. C., and Krumm, W. J., The transonic characteristics of 36 symmetrical wings of varying taper, aspect ratio, and thickness as determined by the transonic-bump technique,** *NACA TN* 3529, 131 pp., Dec. 1955.

An investigation of the effects of planform taper on the aerodynamic characteristics of a series of wings having various tapers, aspect ratios, and thicknesses was conducted in the Ames 16-ft high-speed wind tunnel, utilizing the transonic-bump method. The Mach number range of the investigation was from 0.6 to 1.1, corresponding to a Reynolds number range of about 1.4 million to 2.0 million. The lift, drag, and pitching-moment data are presented for wings having aspect ratios of 4 (taper ratios of 0, 0.2, and 0.5), 3 (taper ratios of 0.14, 0.33, and 0.6), and 2 (taper ratio of 0.33, 0.5, and 0.72), and NACA 63A00X sections with thickness-to-chord ratios of 8, 6, 4, and 2%.

The results indicate that the greatest effect of taper on the lift-curve slope occurred for the wing having the highest aspect ratio and the thinnest section. This effect, which was to increase the lift-curve slope with increasing taper ratio, diminished as the aspect ratio was decreased and/or the thickness increased. Increasing taper ratio generally increased the over-all center-of-pressure travel for all the wings in going from subsonic to supersonic speeds. From authors' summary

1935. **Meyer, R. E., and d'Ews Thomson, T. A., Note on the unsteady heat regenerator,** *J. aero. Sci.* 22, 5, p. 337 (Reader's Forum), May 1955.

Authors investigate carefully the effects of compressibility when the theory in the reviewer's paper [*Aero. Res. Lab. Melbourne, Austral.* A. 78] is applied to a supersonic "blow-down" tunnel. In practice the reservoir exhausts slowly at constant pressure through a porous wad. Assuming the small pressure drop through the wad is negligible, authors calculate the temperature distribution for an arbitrary inlet temperature and the duration of the run at constant outlet temperature. They also show how the lag in temperature transmission increases as the inlet temperature falls. The effects of density variation are shown to be small in practice.

There are two minor accidental misprints: the second term of the equation above (3) should contain the factor $(\theta\theta_2)^{-1/2}$ instead of $(\theta/\theta_2)^{-1/2}$ and the integrand in the expression for $t_{\bullet}\theta^{1/2}/\theta_0$ should be $1/\theta_2{}^{1/2}(r)$ instead of $1/\theta_2(r)$.

A. F. Pillow, Australia

1936. **d'Ews Thomson, T. A., Stagnation temperature control for a blow-down supersonic wind tunnel,** *J. aero. Sci.* 22, 5, p. 340 (Reader's Forum), May 1955.

Experimental results are provided to show that the theory described in the preceding review predicts correctly the period over which the outlet temperature remains constant. With further flow, the outlet temperature falls less rapidly than the inlet temperature. The discrepancy appears to be due to uneven packing in the wad and to a false value of its specific heat.

A. F. Pillow, Australia

1937. **Moore, J. A., Investigation of the effect of short fixed diffusers on starting blowdown jets in the Mach number range from 2.7 to 4.5,** *NACA TN* 3545, 32 pp., Jan 1956.

An investigation was made at Mach numbers of 2.7, 3.0, 3.5, 4.0, and 4.5 to determine the effect of short fixed convergent-divergent wedge diffusers on the starting characteristics of blowdown jets exhausting to the atmosphere. Wedge diffusers that were extensions of the nozzle contours reduced the over-all pressure ratios required for starting to less than one half the values obtained without a diffuser. The minimum over-all pressure ratio required for starting at each Mach number was about twice the value predicted by one-dimensional theory. Central-body diffusers were not so effective in reducing the over-all pressure ratio for starting as were the wedge extensions of the nozzle, except at the higher values of diffuser minimum area. With the wedge extensions of the nozzle contours, the jets could be started for each test Mach number at values of diffuser minimum area that were considerably below the values predicted by one-dimensional theory. The jets could not be started for values of diffuser minimum area that were below those predicted by theory when central-body diffusers were used.

From author's summary

1938. **Hart, R. G., Flight investigation at Mach numbers from 0.8 to 1.5 to determine the effects of nose bluntness on the total drag of two fin-stabilized bodies of revolution,** *NACA TN* 3549, 11 pp., Dec. 1955.

Values of total-drag coefficient were measured for two fin-stabilized, blunt-nose bodies of revolution in free flight at Mach numbers from 0.8 to 1.5. The blunt-nose configurations were designed by rounding off the sharp noses of two previously tested configurations, having nose fineness ratios of about 3 1/2, to radii equal to about 1/4 the maximum body radii.

By comparing the measured values of drag coefficient based on frontal area for the blunt- and pointed-nose models, it is found that, within the accuracy and range of the present tests, rounding off the sharp noses produced no increase in the total drag of either configuration.

From author's summary

1939. **Van Lammeren, W. P. A., Testing screw propellers in a cavitation tunnel with controllable velocity distribution over the screw disc,** *Inter. Shipbldg. Progr.* 2, 16, 573-596, 1955.

Deficiencies of conventional cavitation-tunnel testing of ship propellers are noted, wherein tests under uniform inflow conditions must be interpreted in terms of a radially and circumferentially varying inflow. Theoretical attempts to handle the resultant variation in angle of attack of the blade elements are outlined. No solution is available for propeller cavitation. A cavitation tunnel is needed to reproduce the variable

inflow. Such a new tunnel is described. With an insert (flow regulator) in the nozzle it is possible to individually throttle the flow in various stream tubes. Tests with a regulator of 146 tubes in the 11.8-in. (30-cm) tunnel at Delft Technological University are reported which gave good reproducibility of measured ship wakes.

A new method of carrying out cavitation tests and of evaluating propulsive efficiency is outlined. Results of cavitation tests of a propeller under uniform and wake-type of nonuniform inflows are presented to illustrate the difference in behavior. Included in appendixes are a summary of the theoretical analysis of the effect of inequality of the velocity field and the results of a few systematic tests for determining the relation between thrust and torque coefficients for a propeller in the "open water" and "behind" conditions.

The new type of tunnel, with a flow regulator, represents a major improvement in propeller cavitation tunnels. It should permit considerable improvement in the cavitation performance of ship propellers.

J. M. Robertson, USA

1940. Anonymous, Specifications for AGARD calibration wind-tunnel models (in French and English), *AGARD Publications*, Memo. no. AG 4/M 3, 2 pp. + 4 figs., Aug. 1955.

See AMR 7, Rev. 1609.

1941. Sivells, J. C., Design of two-dimensional continuous-curvature supersonic nozzles, *J. aero. Sci.* 22, 10, 685–692, 732, Oct. 1955.

In the design of many supersonic nozzles, analysis dictates discontinuities in the nozzle curvature. Such discontinuities cannot be matched in the elastic curve of a flexible plate nozzle.

Author presents a method, partially based on that by Riise and Puckett, for the design of continuous-curvature nozzles. Approximations for nozzle length and boundary-layer growth are used. The method of characteristics can be used for determining the perfect fluid profile downstream of the inflection point. Computing forms are given and a typical problem is worked.

The method introduces a number of improvements over earlier techniques.

R. K. Sherburne, USA

1942. Williams, T. J., Pulsation errors in manometer gages, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-92, 17 pp. + 7 figs.

False registration of both the detail and the mean of incident pressure fluctuations is examined theoretically for a manometer gage connected to an air-filled duct. Step and periodic fluctuation amplitudes up to 1 in. of mercury are considered in analyzing connecting lines, line containing inserts of storage and dissipative types, and damping of the manometer liquid. Nonlinearities such as dependence of wave propagation velocity and kinematic viscosity upon fluctuation amplitude are indicated. It is not surprising to find that no signal can register without distortion, and that the proper mean may be exhibited provided all lines are of uniform bore and minimum length, and any damping is truly viscous. A two-liquid differential manometer, which is definitely a laboratory instrument, is described and is said to be capable of indicating the true time-mean of a pulsating head by satisfying these requirements.

Reviewer believes that a recording version designed for field use now needs development.

D. S. Moseley, USA

1943. Kankel, A. V., and Whitten, D. C., Corrugated metal diaphragm performance, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-115, 13 pp. + 2 tables, 10 figs.

This paper presents experimental data showing the effect of the shape of a diaphragm on its performance. The variables investigated include number of corrugations, cone angle, arc angle, diameter, and thickness. Also, the effect of using different materials was observed and a method of comparing the work output of different diaphragms was developed.

From authors' summary

1944. Brombacher, W. G., and Lashof, T. W., Bibliography and index on dynamic pressure measurement, *Nat. Bur. Stand. Circ.* 558, Feb. 1955, iv + 124 pp. $.75.

See AMR 8, Rev. 2493.

1945. Brixner, B., One million frame per second camera, *J. opt. Soc. Amer.* 45, 10, 876–880, Oct. 1955.

The design and construction of a 1,000,000 fps (frame per second) rotating mirror frame camera is described. Twenty five consecutive pictures 20 mm in diam can be obtained on a strip of 35-mm film. A resolution of at least 20 lines/mm is obtained on a moderately fast film like Linagraph Shellburst. Accurate synchronization of the event to be photographed is required. The camera has been most useful in the investigation of explosive and related phenomena.

From author's summary

Thermodynamics

(See also Revs. 1694, 1705, 1706, 1729, 1819, 1827, 1925, 1926, 1927, 1928, 1967, 1969, 1975, 1983, 1992, 1999, 2001, 2002, 2003, 2032, 2039, 2065)

Book—1946. Hilsenrath, J., Beckett, C. W., Benedict, W. S., Fano, L., Hoge, H. J., Masi, J. F., Nuttall, R. L., Touloukian, Y. S., and Woolley, H. W., Tables of thermal properties of gases, Washington D. C., U. S. Dept. of Commerce; Nat. Bureau of Standards Circular no. 564, 1955, ix + 488 pp. $3.75.

A comprehensive collection of tables covering the thermodynamic and transport properties of air, argon, carbon dioxide, carbon monoxide, hydrogen, nitrogen, oxygen, and steam. In the case of hydrogen, oxygen, and nitrogen, both the molecular and atomic species are included. The reported values are based on recent critical correlations of these gases by members of the staff of the National Bureau of Standards. All thermodynamic data and most of the transport data are based on theoretical calculations. Some of the transport properties are based on semiempirical correlations. Values for the compressibility factor, density, entropy, enthalpy, specific heat, specific heat ratio, and sound velocity are presented for pressures up to 100 atm and to temperatures up to 600 K for hydrogen, 1500 K for carbon dioxide, 850 K for steam, and 3000 K for the remaining gases cited above. The thermodynamic functions for an ideal gas are also presented and tabulated uniformly up to 5000 K. Vapor pressure and the transport properties, thermal conductivity, viscosity, and Prandtl number are tabulated over the range of available experimental data. Deviation plots are included to show the range and distribution of the experimental data as well as the agreement of the experimental data with the tabulated values. The large mass of information presented represents a real contribution to the technical literature, and will be of use to engineers and scientists working in areas requiring information regarding thermodynamic and transport properties.

The document contains some 140 tables of properties and an appendix of conversion factors. References to well over 500 sources of information are presented.

G. A. Hawkins, USA

1947. Wooley, H. W., and Benedict, W. S., Generalized tables of corrections to thermodynamic properties for nonpolar gases, *NACA TN* 3272, 62 pp., Mar. 1956.

Tables are presented based on the Lennard-Jones 6-12 potential for nonpolar molecules to be used in the representation of second and third virial coefficients and equation-of-state corrections for enthalpy, entropy, specific heats at constant volume and at constant pressure, the ratio of specific heats, the isentropic expansion coefficient, and the velocity of sound. The treatment for effects involving three molecules jointly uses an empirical adjustment of the Lennard-Jones force parameters within a cluster of three independently of the value for an isolated pair. A graphical correlation of ratios of these parameters with the critical constants is also shown which permits better estimates for compact nonpolar molecules with known critical constants but with limited data of state.

From authors' summary

1948. Keesom, W. H., Bijl, A., and Van Ierland, J. F. A. A., Diagrams of log *p* vs enthalpy for carbon monoxide and for oxygen (in French), *Appl. sci. Res. (A)* 5, 5, 349–358, 1955.

Book—1949. Dzung, L. S., and Rohrbach, W., Enthalpy-entropy-diagram for water vapor and water [Enthalpie-Entropie Diagramme für Wasserdampf und Wasser], Berlin/Göttingen/Heidelberg, Springer-Verlag, 1955, vi + 17 pp. DM 7.50.

The saturated water-steam and superheat diagram with enthalpy as

ordinates and entropy as absissae covers the range 0 to 800 C and 500 bars except for a saturation line cut-off at 110 bars. The diagram is available with or without volume lines.

There is also a saturated water table for each degree to the critical temperature comprising pressure, volume, enthalpy, and entropy. Following the foregoing table there is an entropy-difference, entropy water diagram with constant pressure and temperature lines extending to 600 bars and 370 C.

The diagrams and tables derive from the USSR 1951 edition of the M. P. Vukalovich steam tables which, in turn, are based upon the ASME skeleton tables of 1934 supplemented by Russian p-v-t measurements extending to 600 C and 500 bars and the recent high-pressure water data of G. C. Kennedy.

The units employed throughout are the Georgi advocated system, meter, kilogram, second (ampere); the quantities tabulated are bars, kJ per kg, kJ per kg per degree Kelvin, and m^3 per kg, similar to Prof. O. H. Faxén's Swedish tables of 1953. The advantages of the MKS system of units is emphasized by the authors on the basis of economy of effort and convenience in turbine design.

The tables and diagrams give numerical information agreeing closely with other tables, but the range has been extended beyond most existing compilations.

The printing, quality of paper, and arrangement of material is excellent and a conveniently large page ($8\text{-}\frac{3}{8} \times 12$ inches) has been adopted. Many will hope a definite trend has set in toward the adoption of rational units. F. G. Keyes, USA

1950. **Newitt, D. M., The properties of matter at high pressure** (The Forty-second Thomas Hawksley Lecture), *Inst. mech. Engrs. Preprint*, 16 pp., 1955.

Author's stated purpose is "to give some account of the characteristic properties associated with highly condensed systems and highly stressed materials, as revealed by work carried out during recent years." Three domains of pressure: (1) up to 50,000 bars, behavior of fluid is determined largely by balance between short-range repulsive and long-range attractive forces of atoms and molecules; (2) 50,000 to 1,000,000 bars, solids undergo polymorphic transitions; (3) above 1,000,000 bars, breakdown in structure of matter results in "homogeneous electron phase of high density." Question of a liquid-solid critical is raised but not resolved.

Present status of steam tables is discussed as an introduction to a description of research project under author's direction on measurement of enthalpy of steam to 1000 atm and 750 C by condensation calorimetry. Measurement of high pressures by means of free-piston gage and calibration against a mercury column are described. Compressibility of liquids to pressures as high as 100,000 atm is discussed in terms of the Hudleston diagram. Rapid increase of viscosity with increase in pressure for most liquids is noted.

Transitions of solid phase indicate melting can be followed to temperatures exceeding the critical temperature. As pressures increase, the volume-pressure isotherm will first be broken by discontinuities, and then phase boundaries will disappear. Phase behavior of binary systems at temperatures above and below the critical temperature of the more volatile component shows 1000-fold deviation from Dalton's law. Mixtures of gases with radically different temperatures give two-phase states which cannot be classed as liquid-gas but may be considered gas-gas.

Design of high-pressure precompressed cylinders by shrinking on concentric cylinders is discussed in terms of stress distribution. Bridgman's conical-plug pressure vessel is described. "In principle, it should be possible to increase the strength of a vessel almost indefinitely by adopting a cascade arrangement in which a number of vessels are placed one inside the other...." Effects of hydrostatic pressure on tensile strength and shear strength are generally small, but on strain-to-failure they are large. J. H. Keenan, USA

1951. **Hartung, H. A., Density-temperature-pressure relations for liquid lubricants**, Second Ann. ASLE-ASME Conf., Indianapolis, Ind., Oct. 1955. Pap. 55—LUB-7, 9 pp. + 1 table, 4 figs.

Recently published data on the density of lubricating fluids have been treated to separate the effects of temperature and pressure. Correlations are developed which reproduce the original data within less than 1% in most cases for petroleum fractions, pure hydrocarbons, polymer blended oils, and commercial lubricants. It is expected that the relations found will apply to all liquid lubricants which are principally petroleum hydrocarbons. Density at any temperature up to 425 F and at pressures up to 80,000 psi can be found from the density at room temperature and atmospheric pressure and the viscosity at 100 F.

From author's summary

1952. **Cole, M. B., and Ingersoll, L. R., Second law of thermodynamics apparatus**, *Amer. J. Phys.* 24, 3, 172–173, Mar. 1956.

Satisfactory laboratory apparatus—based on the electric refrigerator—for demonstration and quantitative work with the second law of thermodynamics has been devised and is now in use at the University of Wisconsin and the Missouri School of Mines and Metallurgy. The design and operation of the Wisconsin apparatus is described and the possible calculations discussed. From authors' summary

1953. **Rowlinson, J. S., and Sutton, J. R., The statistical thermodynamics of solutions of non-spherical molecules. I. The thermodynamic functions**, *Proc. roy. Soc. Lond. (A)* 229, 1177, 271–280, Apr. 1955.

The perturbation treatment of the orientational forces between non-spherical molecules proposed by Cook and Rowlinson [title source, 219, p. 405, 1953] is extended to mixtures by using the theory of solutions put forward by Longuet-Higgins [see AMR 4, Rev. 4608]. The thermodynamic functions and the equation of state of such mixtures are expressed in terms of the intermolecular forces and the properties of one pure component. Expressions are derived for the excess (or non ideal) thermodynamic functions which are compared with the experimental results on the four solutions, benzene + cyclohexane, benzene + carbon tetrachloride, benzene + ethylene dichloride, and cyclohexane + carbon tetrachloride. The agreement between theory and experiment is improved by taking account of the orientational forces.

From authors' summary

1954. **Hawthorne, W. R., The thermodynamics of cooled turbines Part I, The turbine stage**, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-186, 25 pp. + 21 figs.

This paper presents an approximate method for determining the influence of gas turbine blade and nozzle cooling on stage efficiency. Methods described permit at least qualitative conclusions to be drawn for the problem that although turbine cooling permits greater turbine inlet temperatures and a theoretical gain in thermal efficiency, the cooling reduces work output and thus may tend to offset the expected increase in efficiency.

After determining expressions for stage efficiency of uncooled and cooled turbines by usual thermodynamic analysis, author assumes that cooling significantly effects only the profile (skin friction) losses. Treating the flow through nozzles and blading as one-dimensional compressible flow through a conical duct, author uses the Reynolds' analogy to estimate the profile loss. In discussion, author clearly points out the approximation involved in this application of the Reynolds' analogy.

Author concludes that cooling is best suited to the rotating blades of impulse or small-reaction-type turbines with only slight nozzle cooling. High blade velocities and low pressure ratios are also desirable. The author believes that, in this type of turbine, cooling will not have a large effect on stage efficiency but will reduce the reheat factor, resulting in a significant decrease in the work output. Some discussion of coolant requirement is included. R. L. Young, USA

1955. **Hawthorne, W. R., The thermodynamics of cooled turbines. Part II, The multistage turbine**, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-191, 11 pp. + 3 figs.

Paper presents a rapid method for calculating the reheat factor and turbine efficiency for multistage uncooled and cooled turbines. This method is based on stage efficiencies determined by the means proposed in part I [see preceding review]. A chart is presented to facilitate the calculations and the results obtained compare well with more lengthy, exact solutions. R. L. Young, USA

1956. **Devienne, F. M., Total pressure in free molecular flow** (in French), *C. R. Acad. Sci. Paris* 242, 1, 67–68, Jan. 1956.

1957. **Hours, R., Measurement of the concentration of gas in a gas-liquid emulsion by absorption of γ rays** (in French), *Houille blanche* 10, special B, 636–645, Sept. 1955.

By measuring the "optical density for γ rays" of a gas-liquid emulsion, the average concentration of gas in the zone traversed by the beam of radiation can be obtained. The beam does not perturb the nature of the emulsion.

The γ energy selected will be a function of the thickness of the emulsion and, for aqueous emulsions, the upper limit of this thickness is about 1 m.

The accuracy will be proportional to the concentration of gas, to the thickness of the emulsion, and to the absorption coefficient of the liquid, and thence to the square roots of the source strength, the detector efficiency, the duration of the measurement. With low concentrations the precision is poor, but in certain cases it can be better than 1%.

The statistical aspects of the measurement have been studied.

The same equipment can be used for density determinations in many other systems, particularly suspensions in which the dispersed phase has a density which is notably different from that of the medium.

From author's summary

1958. **Gentry, G. C., A missile air-gas pressurization system**, *Jet Propulsion* 26, 100–101 (Technical Notes), Feb. 1956.

1959. **Miller, E. H., and Sidun, A., Economic determination of condenser and turbine-exhaust sizes**, *Trans. ASME* 77, 3, 373–381, Apr. 1955.

1960. **Pieślak, W., Modern methods of determining degree of contamination of air and gases in industrial centers** (in Polish), *Przegl. tech.* 75, 3, 98–100, Mar. 1954.

1961. **Molde, P., Does negative energy exist** (in Danish), *Ingeniøren* 64, 26, 558–559, June 1955.

The title is a question and author gives no answer. He starts from the hypothesis that time is quantized and gives a formal deduction of Einstein's mass-energy equation. By introducing imaginary time we obtain a formally positive metric in the theory of relativity. By this formal method author gets a negative mass conception. As long as author cannot theoretically declare any hitherto unsolved problem I cannot judge the value of his ideas. Author finds the following question interesting: Is the total mass in universe equal to zero?

B. Andersson, Sweden

Heat and Mass Transfer

(See also Revs. 1705, 1706, 1809, 1846, 1852, 1853, 1860, 1935, 1936, 1952, 1953, 1958, 1959, 2009, 2010, 2011, 2012, 2013, 2049, 2052)

1962. **Keller, G. J., and Ballard, J. H., Predicting temperature changes in frozen liquids**, *Indust. Engng. Chem.* 48, 2, 188–196, Feb. 1956.

Authors measure conductivity, specific heat, and density of orange juices of various concentrations. They compare experimental freezing curves for cylindrical symmetry with calculated curves, lumping, in the calculations, the latent heat of fusion into an enlarged specific heat term.

G. Horvay, USA

1963. **Jaeger, J. C., Numerical values for the temperature in radial heat flow**, *J. Math. Phys.* 34, 4, 316–321, Jan. 1956.

Author has tabulated the radial temperature response of an infinite medium of uniform thermal diffusivity α bounded internally by an infinite circular cylinder of radius a. The region is initially at a uniform temperature, and the temperature of the cylindrical surface $r = a$ is suddenly changed to and maintained at a uniform value for all time $t > 0$. The tabulation is to three significant figures, and covers a range of $1 \leq r/a \leq 100$ and $0.001 \leq \alpha t/a^2 \leq 1000$. The solution is also reported to apply to the academic case of a semi-infinite solid $x > 0$ whose thermal conductivity increases linearly with x.

P. J. Schneider, USA

1964. **Evans, G. W., Brousseau, R., and Keirstead, R., Stability considerations for various difference equations derived for the linear heat-conduction equation**, *J. Math. Phys.* 34, 4, 267–285, Jan. 1956.

Authors of this paper discuss the notions of stability, convergence, and error propagation in connection with obtaining a numerical solution of a difference equation representing a linear differential equation. It is shown that, while these notions are essentially independent, the properties of stability, convergence, and error growth influence one another in a rather complex way. For example, computational round-off errors are shown to be related to stability only insofar as the former effects the latter by a particular pattern of error control. The effect of initial and boundary conditions on the stability of the differencing scheme is discussed, and a definition of stability of difference equations is suggested and interpreted in connection with von Neumann's method of stability analysis. Finally, a procedure is suggested for estimating errors in the calculation of a numerical solution for a difference equation taken to represent a partial differential equation.

P. J. Schneider, USA

1965. **Vogel, L. C., and Krueger, R. F., An analog computer for studying heat transfer during a thermal recovery process**, *J. Petr. Technol.* 7, 12, 205–212, Dec. 1955.

Solution of several heat-conduction problems occurring in oil field recovery and involving heat source moving radically outwards through cylinder is carried out on $R-C$ network computer. Constant temperature source, represented by battery, is connected to successive nodes by motor-driven rotary switch. Voltage profile is observed by photographing oscilloscope screen.

Reviewer finds insufficient information regarding alleged innovations in computer design; e.g., to represent modes of heat transfer other than conduction. Paper is helpful in introducing computer techniques to new groups.

V. Paschkis, USA

1966. **Vernotte, P., Generalization of a practical integration procedure for partial differential equations. Application to the diffusion of mass and heat** (in French), *C. R. Acad. Sci. Paris* 241, 24, 1699–1700, Dec. 1955.

The diffusion equation $(DC_x)_x = C_t$, where C is the concentration of mass or heat, D the diffusion coefficient, and subscripts indicate partial differentiation, has solution C a function of $u = x^2/t$ if D is a function of C and the boundary conditions are appropriate. Such a solution might be used to determine D experimentally from a measured C. Author extends this relation between C and D to the case where C has a small part depending on x and t otherwise than through u. D then has a corresponding small part depending on x as well as C.

C. M. Ablow, USA

1967. **Vetrov, B. N., and Todes, O. M., Heating granulated material by conduction along a cylindrical vessel at non-adiabatic conditions. II.** (in Russian) *Zh. tekh. Fiz.* 25, 7, 1232–1241, July 1955.

This paper is the second one on the same subject published in the same issue of title source, 25, 7, July 1955. In the first paper, under the title "Measuring the coefficient of heat transfer from a flowing gas to a furnace charge," authors report on their investigations of heating a charge of granulated material in a cylindrical vessel by blowing hot air through it. The measurements gave a temperature-time curve from which authors evaluated heat transfer and other thermal coefficients of the charge, assuming heat-transfer by forced convection only and neglecting heat conduction. At large gas velocities, the thermal coefficients found experimentally gave good agreement with the established Nusselt number-Reynolds number relation for the forced convection. At small velocities, discrepancies appeared, due to conduction heat transfer along the charge itself, which was negligible at large velocities as compared with the forced convection heat transfer from the gas to the charge, but not so at small gas velocities.

In this paper, authors present results of heating a charge of granulated material by conduction only along the same cylindrical vessel. Theoretical solution was obtained in two stages. The first approximation was obtained by assuming that the charge is a solid cylinder (instead of porous granulated mass), and the boundary-value problem for the actual case was solved with the help of this first approximation. The experiments consisted of heating only the front of the charge and letting the heat be transferred by conduction along the charge (not letting the hot air through it), and plotting temperature-time curves. The

experimental results agree with the theoretical solutions and authors are able to introduce a correction in their original results to make them agree with Nusselt number-Reynolds number relation.
T. Leser, USA

1968. **Vetrov, B. N., and Todes, O. M., Propagation of heat waves due to the heating-up of furnace charges by a gas flow, III,** (in Russian), *Zh. tekh. Fiz.* 25, 7, 1242–1247, July 1955.

This is the third and the final paper by the same authors on the subject of finding the coefficient of heat transfer from a hot gas flowing through a granulated material along a cylindrical vessel. The three papers appeared in the same issue of title source, 25, 7, July 1955, and are being reviewed currently. In the first paper under the title: "Measuring the coefficient of heat transfer from a flowing gas to a furnace charge," authors assumed only forced convection and neglected heat transfer by conduction. In the second paper under the title: "Heating granulated material by conduction along a cylindrical vessel at non-adiabatic conditions," authors describe an investigation of heat transfer along the same charge by conduction only. In this report, authors present the mathematical solution of the heat equation with boundary conditions existing in their experimental set-up, in which they take into account both forced convection and conductivity along the vessel. The solution giving the temperature as a function of time and distance from the front of the charge provides a formula for finding the convection heat transfer from the gas and the conductivity of the charge. As the conductivity at small velocities (small Reynolds numbers) cannot be neglected, authors propose a modified Nusselt number which would take this into account for small values of Reynolds number (in the relation Nusselt number-Reynolds number for forced convection). This would enable people in industry to evaluate directly the width of the heat wave in which they are mainly interested, without bothering about convection and conduction.
T. Leser, USA

1969. **Kanter, K. R., Instant heat-source method for the determination of thermal characteristics** (in Russian), *Zh. tekh. Fiz.* 25, 3, 472–477, Mar. 1955.

Author presents a method for finding experimentally the coefficient of thermal diffusivity α (m^2/hr) and the coefficient of heat conductivity λ (kgcal/meter/hr/°C) for thermal insulators and refractories. His method is an improvement of the Kulakov method, which he describes at the beginning.

Kulakov method consists of placing an electric heater between two thin plates of the investigated material and then placing both plates with the heater between two thick plates of a material with known thermal coefficients. The thick plates form a calorimeter. Both ends of a thermocouple are inside the calorimeter, the hot end near the plate of the investigated material. An electric current flows through the heater in a fixed interval of time, generating a known amount of heat. The temperature and the time are measured from the instant the current was switched on. The coefficients α and λ are evaluated from the maximum temperature read and from the time in which this maximum was reached. The formulas used and the references are given.

The improvement introduced by author consists of placing the hot end of the thermocouple at a point in the plane of contact of a plate of the investigated material and the calorimeter plate. He claims the following advantages for his method: (1) Temperature maximum is much sharper than in Kulakov method; (2) the coefficients α and λ are more accurate due to sharp temperature maximum; (3) experiments last only 2–10 minutes, as compared with 5–20 minutes for Kulakov method; (4) formulas are simpler and the computations require only a few minutes.

Author gives a detailed description of the experimental set-up, lists the instruments, and gives the sequence of steps during an experiment.
T. Leser, USA

1970. **Goldfarb, E. M., Heating of solids of several shapes by gases in parallel and counter flow** (in Russian), *Zh. tekh. Fiz.* 24, 6, 1012–1019, June 1954.

Author obtains 'exact' solutions for transient heating of metal billets of square and round profiles, and also for metal spheres, when heated by a gas stream. Newton's law of cooling, used in the analysis, is hardly acceptable for the extreme temperature ranges considered, and the solutions can, at best, be regarded as exact in the mathematical sense only. Also, without further clarification, the boundary conditions used are open to question, in particular condition (1,4). A numerical example yields the remarkable result that the gas temperature rises on heating a billet, which is in disagreement with the initial physical conditions presented by the author.
Y. R. Mayhew, England

1971. **Shabanov, S. I., Heat conduction in a cylinder of finite dimensions in continuous quasistationary heat conditions** (in Russian), *Zh. tekh. Fiz.* 24, 5, 907–909, May 1954.

The determination of thermal properties of humid materials at a stationary regime involves certain errors due to changes in humidity. This affects particularly the coefficient of diffusivity (sq m/hr) because the cooling of the calorimeter is accompanied by a large and rapidly changing temperature gradient in the investigated material. The accuracy can be considerably improved if the measurements are made at a quasi-stationary regime when the humidity practically does not change.

To evaluate the thermal coefficients from experiments at a quasi-stationary regime the author derives formulas from the solution of a boundary-value problem involving the heat equation and boundary conditions for a cylindrical calorimeter. He presents different formulas for small and for large length-radius ratios. The mathematical procedure is shown in every detail.
T. Leser, USA

1972. **Meiman, N. N., On the equation of heat conduction** (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* 99, 2, 209–212, 1954.

This is a mathematical investigation of the equation

$$(\partial u/\partial t) - D(\partial^2 u/\partial x^2) - A(\partial u/\partial x) - Bu - Q = 0$$

where A, B, D, Q are functions of the independent variables. Under fairly general assumptions, the unique existence of analytical solutions satisfying preassigned initial conditions is proved. By substituting the ratio of differences for differential coefficients, a system of simultaneous equations is set up; it is proved that the solutions of this system converge toward the analytical solutions of the differential equation. These theorems are generalized—again under fairly general assumptions—so that they apply to nonlinear equations, i.e., equations where A, B, D, Q are functions of u.

For nonmathematicians the theorems regarding nonlinear equations may be important; in addition, the paper contains the justifications of familiar numerical methods.
R. Eisenchitz, England

1973. **Schuh, H., Transient temperature distributions and thermal stresses in a skin-shear web configuration at high-speed flight for a wide range of parameters,** *J. aero. Sci.* 22, 12, 829–836, Dec. 1955.

Transient temperature distributions and thermal stresses are calculated for a typical wing I-section composed of a cover plate and a shear web, and the results are presented in the form of charts for a range of parameters. Web receives heat from the cover plate by conduction only; cover plate is heated aerodynamically. Resulting linear differential equations do not include any temperature discontinuity at the interface of web and cover plate, and heat transfer to the inside of the wing is neglected. Nondimensional governing equations are solved by finite difference methods. Simplified solution assumes that web distance is at least equal to half the web height. Influence of radiation is included in a limiting case.
F. V. Pohle, USA

1974. **Hasselgruber, H., The joining of friction clutches and brakes with regard to the smallest maximum temperature** (in German), *Forsch. Geb. Ing.-Wes.* (B) 20, 4, 120–125, 1954.

An interesting study of the physical phenomena incident to the clutching operation of cone-type clutches during engagement period. The paper is divided into three main parts: method of calculation of heat generated, method of calculation of temperature rise, and method of calculation of optimal clutching period. Four sets of curves are given in dimensionless form. These represent as functions of fraction of clutching time, the heat generated, temperature rise, relative speed of parts, and frictional moment.
W. H. Hoppmann, II, USA

1975. **Leidenfrost, W., Heat damping effect of fine pulvers in rarified gases** (in German), *ZVDI* 97, 34, 1235–1242, Dec. 1955.

Fine pulverized materials evenly scattered in gases have very low thermal conductivity if the distances between grains (diam $< 0.1\mu$) are of the same order as the free path of molecules (Smoluchowski 1910).

Author reaches the necessary vacuum (1–10 Torr) by condensing the vapor (CCl_4) or by absorbing the gas (CO_2) with which he fills the insulating space of the container. The density of the powder (e.g., aerosil) is raised to a sufficient degree (100 kg/m³) by deformation of the pliable outer walls of the vessel under atmospheric pressure. The cooling-down curve of such an experimental vessel does not differ very much from that of a normal Dewar bottle. O. Mástovský, Czechoslovakia

1976. Coppage, J. E., and London, A. L., Heat transfer and flow friction characteristics of porous media, *Chem. Engng. Prog.* 52, 2, 57-F–63-F, Feb. 1956.

Convective heat-transfer and flow-friction data have been obtained for matrixes composed of woven wire screens and spheres in the Reynolds number range from 5 to 1000. Data for closely packed screens cover a range of porosities from 0.60–0.83; data were also obtained for one separated screen matrix. The data for spheres were obtained for one randomly packed condition, $\alpha = 0.39$.

Previous heat-transfer data are limited, but agreement with present results was generally found within the expected experimental uncertainty limits. Previous flow-friction data are plentiful, but inadequate geometric descriptions reduced greatly the amount of information which could be compared directly with the present results. Excellent agreement between present and previous results was found for screens and spheres. Results for granular media fall in the same region occupied by screen matrixes.

An empirical correlation is presented for the heat-transfer behavior of porous media based on the screen and sphere matrixes behavior. This correlation indicates that the heat-transfer behavior is strongly influenced by porosity. Additional data on granular media are needed to establish the correlation more firmly for application to commercial packings.

No satisfactory correlation for flow-friction behavior of porous media was found. Data for packed screens and a wide variety of granular media fell into a definite range, but the spread is too large to be termed a correlation. The spreads could be materially reduced by dividing the granular media into matrixes composed of solid bodies and matrixes of bodies with holes through them. From authors' summary

1977. Savage, L. H. W., and Ashton, M.D., Ingot heat conservation. Cooling of 15-ton ingots between teeming and stripping, *J. Iron and Steel Inst.* 179, part II, 132–142, Feb. 1955.

The rate of heat loss from the mid-height section of a 15-ton rimming-steel ingot has been determined for 12 casts. It can be represented as a function of time from start of teeming t and initial mold temperature θ by the regression equation

$$H_S/\sqrt{t} = a + b\theta + ct + dt^2$$

or with slightly greater error by $H_S/\sqrt{t} = k$, where H_S is the heat loss from the steel, and a, b, c, d, and k are constants the values of which have been determined. Increase in initial mold temperature causes a decrease in the rate of heat loss. It is possible to determine initial mold temperature from the time which has elapsed since the mold was stripped.

By making certain simplifying assumptions, the average thickness of solidified shell S can be expressed by the equation

$$S = K\sqrt{t}$$

From a limited number of measurements at points other than on the mid-height plane, the average heat loss per unit mass of the ingot was calculated to be about 25% greater than that at the mid-height section.

From the results it is possible to recommend a reduction in standing time between teeming and stripping, which will result in a saving of fuel in soaking pits. From authors' summary

1978. Neimark, B. E., Thermal conductivity of steel (in Russian), *Teplo energetika* no. 9, 22–26, 1955.

1979. Zozulia, N. V., and Dyban, E. P., Scientific and technical session on heat transfer in isotropic media (in Russian), *Teplo energetika* no. 9, 61–63, 1955.

1980. Sellars, J. R., Tribus, M., and Klein, J. S., Heat transfer to laminar flow in a round tube or flat conduit The Graetz problem extended, *Trans. ASME* 78, 2, 441–448, Feb. 1956.

An asymptotic method completes the set of eigenvalues and eigenfunctions for Graetz's solution for the temperature distribution in the fluid of constant properties at constant wall temperature. With these results the solution is extended to include generalized boundary conditions, namely arbitrary wall-temperature or heat-flux variations. Data given by Lipkis in Discussion are even more accurate than those of Schenk and Dumoré [AMR 7, Rev. 4030]. H. A. Vreedenberg, Holland

1981. Graf, D. A., and Street, R. E., Experimental investigation of laminar heat transfer from a uniformly heated flat plate at Mach 2.5, *Trend. Engng. Univ. Wash.* 8, 1, 27–32, Jan. 1956.

From the data this investigation has produced the following summary may be made:

(1) The Chapman-Rubesin theoretical curve for heat transfer through laminar boundary layers holds true in the lower Reynolds number range of from 19,000 to 195,000. (2) Heat-transfer data may be taken for either a heated or a cooled plate without any sacrifice in accuracy. (3) Boundry-layer separation has a very noticeable effect on the rate of heat transfer. (4) Moisture and turbulence in the air have a decided effect on the temperature recovery factor. (5) It is possible to heat a model to a uniform surface temperature and thus forego any analytical corrections of the heat-transfer data. From authors' summary

1982. Seban, R. A., and Doughty, D. L., Heat transfer to turbulent boundary layers with variable free-stream velocity, *Trans. ASME* 78, 1, 217–223, Jan. 1956.

Local turbulent heat-transfer coefficients were measured on a plate in subsonic air flow. (Maximum flow velocities ranged from 200 to 900 fps.) The free-stream velocity was nearly constant over the initial portion of the plate, followed by a strong acceleration and a subsequent gradual deceleration. Heat-transfer coefficients were affected substantially by the acceleration. Methods of predicting the heat transfer based on constant properties were found to be satisfactory, provided the thermal history of the flow was accounted for. Results are given also for constant velocity along the plate, both for a completely turbulent flow and for turbulent flow occurring after natural transition.

From author's summary by G. M. Low, USA

1983. Katz, E. L., The determination of heat-transfer coefficients for air and carbon dioxide, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55—A-101, 18 pp. + 12 figs.

An experimental investigation was conducted for determining the convection and radiation heat-transfer coefficients for pure dry air and pure gaseous carbon dioxide flowing turbulently through a small-diameter, water-cooled tube. The experimental results are correlated with an average deviation of ±8% by the following equation: $j = 0.035Re^{-0.23}$, wherein all physical properties are evaluated at the average film temperature. Data were obtained over a static gas pressure range of 50 to 250 psia, an average gas bulk temperature range of 597 to 1778 F, and a Reynolds number range of 8300 to 140,000. The total heat-transfer coefficients for carbon dioxide, which contain both radiation and convection components, are shown to be numerically less than the pure convective coefficients for air at the same conditions of temperature, pressure, and Reynolds number. The total coefficients for CO_2 are shown to be affected by pressure at high bulk temperatures. For example, at an average bulk temperature of 1550 F, the total coefficient decreased 9% when the pressure was increased from 50 to 200 psia.

From author's summary by J. Hilsenrath, USA

1984. Rohsenow, W. M., Effect of turbine blade cooling on efficiency of a simple gas turbine power plant, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55—A-120, 13 pp. + 14 figs.

The cycle efficiency for cooled gas turbines has been estimated over a range of pressure ratio and turbine inlet temperature with varying assumptions for the temperature at which the gases leave the cooled portion of the turbine. The cooling reduces the temperature at entrance to the succeeding stages. This effect of cooling is included, but the small effect on the stage efficiency is neglected. The results show that raising the turbine inlet temperature increases the efficiency considerably, provided the blades are designed so that heat transfer is minimized.

The several curves also show that, with high temperature cooled turbines in which the number of stages cooled depends on the quality of the blade material, the loss in efficiency due to using less heat-resistant material is only a few per cent. W. R. Hawthorne, USA

1985. **Johnson, H. A., Heat transfer and pressure drop for viscous-turbulent flow of oil-air for mixtures in a horizontal pipe,** *Trans. ASME* 77, 8, 1257–1264, Nov. 1955.

Continuation of work on two-phase flow with comparison with previously published data on air-water system. Tentative empirical correlations are proposed but indicate need for including additional factors, such as flow patterns, before different systems can be successfully correlated. Significant contribution is the effect of flow rates and ratios on heat transfer and pressure drop and that these effects are different in each system. Reviewer believes better correlations might be possible if h_{TP}/h_G were used instead of h_{TP}/h_L. Since liquid flow was viscous, the selection of h_L completely defines a test, while the turbulent flow h_G has more degrees of freedom. A. C. Mueller, USA

1986. **Low, G. M., The compressible laminar boundary layer with fluid injection,** *NACA TN* 3404, 29 pp., Mar. 1955.

Author has done an excellent job in presenting a solution of the equation of the compressible boundary layer. Direct solution of the boundary-layer equations is carried out to include the effects of transpiration cooling. Similar velocity and temperature profiles are obtained because of the assumption for the normal transpiration velocity at wall. These profiles are used further in a stability analysis.

Reviewer believes that, although the problem has been freed of many limitations associated with the integral or empirical method of solving the boundary-layer equations, the direct solution is much more tedious and less adaptable to changes of assumptions. Furthermore, the results would appear to be qualitatively the same for any method. The stability analysis is considered to be an important result of the direct method of solution.

Author's summary states: "The effect of several flow parameters on coolant flow rates is discussed. A stability analysis indicates that, although transpiration cooling requires a lower surface temperature for stable flow than does internal wall cooling, this lower temperature can be obtained with a smaller expenditure of coolant."

B. L. Buteau, USA

1987. **Eckert, E. R. G., Diaguila, A. J., and Livingood, J. N. B., Free-convection effects on heat transfer for turbulent flow through a vertical tube,** *NACA TN* 3584, 24 pp., Dec. 1955.

Effects of natural convection on forced convection heat transfer were investigated for vertical tubes having L/D up to 40. Report is particularly useful in mixed free-forced flow region where information is scarce.

Data obtained from *NACA TN* 2974, 1953 (Ref. 1) and *Trans. ASME* 76, 553–562, 1954 (Ref. 2) were evaluated on same basis. Ref. 1 deals with 24-in. diam tube, L/D up to 5, using air from atm to 125 psia. Ref. 2 deals with 0.2101-in. diam tube, L/D up to 40, using heated water up to 2000 psia. Heat flowed from wall to fluid. Fluid flow was opposite to acceleration of gravity in both references.

Authors state that conclusions made with Ref. 1 appear valid for Ref. 2. The limit between forced and mixed flow is

$$Re = 8.25(Gr\,Pr)^{0.40}$$

and the limit between mixed and free-flow is

$$Re = 15(Gr\,Pr)^{0.40}$$

Gr and Re are based on distance x rather than diameter. McAdams rule of choosing the higher coefficient obtained from free flow and forced flow for the mixed-flow region is recommended, but the coefficients will be somewhat too large. Reviewer believes that this may possibly be an understatement since differences up to 40% can be observed from the curves. However, authors were reluctant to base a new recommendation from this one report. G. Theoclitus, USA

1988. **Martin, J. J., and Carmichael, M. B., Combined forced and free convective heat transfer in a horizontal pipe,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55—A-30, 6 pp. + 6 figs.

Besides a summary of previous work on this subject, experimental results are reported of local coefficients of heat transfer for laminar flow in a horizontal tube both with and without a hydrodynamic entrance section. An equation is derived from the experimental data giving account of the influence of both free and forced convection on the coefficient of heat transfer. J. A. Businger, Holland

1989. **Hallman, T. M., Combined forced and free-laminar heat transfer in vertical tubes with uniform internal heat generation,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55—A-73, 24 pp. + 7 figs.

Paper presents a mathematical solution which describes the temperature and velocity fields in superposed free and forced laminar convection in vertical cylindrical pipes. Uniform internal heat generation within the fluid may or may not be present and a uniform heating or cooling at the tube wall is considered. The solution is intended to be applicable at a distance far downstream of the entrance, where the velocity and temperature profiles are assumed to become independent of the axial coordinate. A comparison is made between this solution and the small amount of experimental data available in the literature. The analysis is based on the postulate that the axial temperature gradient is everywhere uniform. Reviewer believes that the conditions under which this assumption is applicable must be determined by experiment before this solution can be used for predicting the behavior of real systems.

D. C. Hamilton, USA

1990. **Somers, E. V., Theoretical considerations of combined thermal and mass transfer from a vertical flat plate,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55—A-48, 7 pp.

Author solves simultaneously the boundary-layer equations of motion, of energy, and of diffusion by neglecting the viscous dissipation but including the free-convection terms for a vertical flat plate. This analysis is more general than most of the previous analyses. The method of solution used is the von Karman-Pohlhausen method, in which three integral equations are used for four unknowns; the maximum velocity of the gas parallel to the plate u_x, and the boundary-layer thicknesses of the velocity profile δ, of concentration profile δ', and of temperature profile δ''. The fourth relation is arbitrarily assumed either $\delta = \delta' > \delta''$ or $\delta = \delta'' > \delta'$. Solutions for both of these fourth relations have been worked out.

Comparison of the present results with other simple analyses by previous investigators are mentioned. General formula for Nusselt number in terms of Grashof number is given. An example of the wall of a heated tank containing Freon-11 (CCl_3F) to be cooled by wetting the walls with pentachloradiphenol ($C_{12}H_5Cl_5$) is given. S. I. Pai, USA

1991. **De Vos, J. C., Evaluation of the quality of a blackbody,** *Physica* 20, 10, 669–689, Oct. 1954.

A blackbody, as discussed in this paper, consists of an opaque hollow body whose internal walls emit radiation. The body contains a small hole, the emissions from which can be used for emissivity or photometric measurements. Deviation of this emissivity from ideal blackbody radiation, i. e., quality of the blackbody, will depend on various factors, such as details of the geometry of the blackbody, wall temperature distribution, and nature of the internal reflection. In previous methods of computing quality of blackbodies, it is assumed that reradiation is isotropic, and it is difficult to take variations of temperature over the surface into account. In present method, integration is performed over all angles of reradiation from all surface elements, so that nature of reradiation as well as temperature distribution can be taken into account.

Reviewer feels present method is useful when the angular distribution of the reradiation is known, and in certain geometries; for example, in long cylinders, where the variation of the source strength with position is small. In other common geometries, however, method can lead to cumbersome integrals. R. L. Mela, USA

1992. **Hottel, H. C., A survey of residential uses of solar energy,** Godfrey L. Cabot Solar Energy Conversion Research Project, Mass. Inst. Technol. Publ. no. 60, 12 pp. + 10 figs., 1955.

An excellent paper (presented at the Arizona Solar Energy Symposium in November 1955) worthy of careful study by all interested in solar energy. The reasons why domestic applications of solar energy show more promise than all others are clearly delineated, and a basis is

given for evaluating the significance of the many technical and economic factors that enter into solar heating. Author discusses solar radiation, solar collection devices, the supply of domestic hot water, solar heating and cooling of houses, and the guiding principles of design of solar heating equipment. It is pointed out that future use of solar energy hinges largely upon learning how to cheapen the construction cost of flat-plate solar collectors. A. Whillier, South Africa

1993. **Juhasz, S. I., and Hooper, F. C., Hydraulic analogy applied to crossflow heat exchangers,** *Proc. second U. S. Nat. Congr. appl. Mech.* June 1954; Amer. Soc. mech. Engrs., June 1955, 805–810.

When the reviewer invented the Hydrocal, an hydraulic analog for solving heat transients, he certainly did not envisage the adaptation as conceived and suggested by Prof. Matts Bäckström, and so admirably worked out and presented by Juhasz and Hooper. By an extension of the highly ingenious device of letting area in the prototype correspond to time in the model, which the authors employ for one-dimensional problems, and by using several pairs of connected bottles and a rotary multiple valve, the authors have made the model yield solutions of crossflow heat-exchanger problems. Direct solutions can be made, even when involved with complicated geometries, variable specific heat, and heat leakage.

It is a privilege to have the opportunity to write this review of an ably written paper, presenting, as it does, a welcome contribution to our techniques for dealing with some very difficult and important problems.
A. D. Moore, USA

1994. **Stevens, R. A., and Woolf, J. R., Mean temperature difference in one-, two-, and three-pass crossflow heat exchangers. Part I. Counter current exchangers,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-90, 9 pp. + 2 tables, 11 figs.

Theoretical mean temperature differences are reported for the first time for all practical cases of the counter-cross flow type. Presentation of design data is in the form of correction factors relative to pure counterflow, obtained by (cyclic) iterative numerical integration [see AMR 7, Rev. 315]. H. H. Korst, USA

1995. **Fernandez, J., and Woolf, J. R., Mean temperature difference in one-, two-, and three-pass, crossflow heat exchangers. Part II. Cocurrent exchangers,** ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55-A-89, 6 pp. + 2 tabs., 11 figs.

Form of presentation and method of calculation (except for iteration, which is not necessary) is the same as in the preceding paper.
H. H. Korst, USA

1996. **Tigges, A. J., Karlsson, H., Lower flue-gas exit temperatures through removal of the solids ahead of the air preheater,** *Trans. ASME* 78, 2, 305–315, Feb. 1956.

BOOK—1997. **Hansson, S. A., Birger and Fredrik Ljungström—inventors,** (Also available in Swedish), Stockholm, Nordisk Rotogravyr for International STAL Company, 1955, 123 pp.

Combustion

(See also Revs. 1705, 1706, 1862, 1875, 1968, 1996, 2039, 2040, 2041, 2042)

Book—1998. **Combustion researches and reviews, 14 papers,** (AGARDograph no. 9), London, Butterworths Scientific Publications, 1955, xv + 187 pp.

Papers from the 1954 AGARD(NATO) Combustion Panel meetings, and the first volume of a proposed series to aid design of high-altitude, high-performance aircaft engines. Barr reviews the literature on diffusion flames. Gerstein and also Kling cover the formation and properties of fuel sprays, underlining the utility of the Mugele and Evans upper-limit size distribution equation. Graves and Gerstein, also Joyce, analyze the combustion of fuel sprays, and show the need of small-size droplets.

Several authors discuss flame stability. Longwell analyzes baffles and concludes that can stabilizers need more study. Mestre considers the effect of many parallel flow paths. Mullins feels that much greater combustion intensities are realizable, particularly by faster and differential mixing. Zukoski and Marble demonstrate the importance of wake transition on flame-holding.

Porter deduces that combustion and homogeneous gas-phase pyrolysis have the same mechanism, since the carbon particles formed are similar. Foure finds that carbonization is not important in present turboreactors, but may become so.

Penner analyzes scaling-up of gas and of liquid-fuel rocket engines under various conditions. Codegone takes up the effect of radiation from the flame on the scaling-up.

Included are 42 recommended combustion terms and their definitions in English and French. C. F. Bonilla, USA

1999. **Williams, K. G., Johnson, J. E., and Garhart, H. W., Sampling studies of cool flames,** *Indust. Engng. Chem.* 47, 12, 2528–2532, Dec. 1955.

A study of the effect of sampling probe characteristics on the percent oxygen distance profile in an *n*-hexane cool flame stabilized in a flow system furnace. In most cases, a long uniform-diameter glass tube was inserted in the exhaust end and percent oxygen measured continuously with a paramagnetic oxygen meter. Thermocouple temperature profiles also were taken. Appreciable reaction was found in probes as small as 0.6-mm I.D. In all cases, increased gas velocity in probe decreased probe reaction. A minimum in analyzed oxygen content was found when probe tip was near the "flame temperature rise," and when sampling was slow led the authors to formulate a "probe-reaction hypothesis." They assume that surfaces inhibit the formation of chain initiators but the intermediate products of chain branching reactions are more susceptible to surface than homogeneous oxidation. This was tested with probe modifications which gave qualitative agreement with theory. The authors' data suggest to the reviewer that gas residence times of less than 0.1 sec in the hot probe region are necessary to measure correct oxygen profiles in cool flame studies. R. A. Strehlow, USA

2000. **Berl, W. G., Rice, J. L., and Rosen, P., Flames in turbulent streams,** *Jet Propulsion* 25, 7, 341–346, July 1955.

Because of the complexity of the interaction between chemical reaction and the aerodynamics of mixing in turbulent flow, four different models are proposed to evaluate the increase of combustion rates by turbulent motion. These models represent extreme cases rarely found in real combustion conditions, but they illustrate some fundamental findings; for example, a too vigorous mixing would have as a result a lowering or cessation of the heat release.

The influence of turbulence on combustion was experimentally studied with pentane air flames. High-speed schlieren pictures showed cell structure of the flame front. Heat-release rates are given for a variety of experimental conditions. To avoid disturbances in the boundary layer near the nozzle wall, further experiments were made with inverted Bunsen flames, which were stabilized at the tip of a capillary tube through which small quantities of hydrogen were passed. When turbulence was produced by introduction of wire meshes the flame broke up into a large number of cellular structures. Variation of mixture composition showed the cell formation to be particularly pronounced on the rich side of the stoichiometric air/fuel ratio for the pentane-air flame. H. Behrens, Germany

2001. **Lutz, O., Technical thermodynamic reaction** (in German), *Z. Flugwiss* 3, 6, 151–159, June 1955.

An attempt is made to bring the technical thermodynamics of change of state under simultaneous reaction—the technical thermodynamics of reactions—into a uniform and precise pattern. Introducing the enthalpy of reactions, tables of state of reacting mixtures of gases can be produced. According to the latest trend of thought one is inclined to believe that even under outflow conditions at high velocities equilibrium exists throughout—at least more likely than the rigid condition of state; and therefore such tables are the first predication for any reliable thermodynamic estimate. The physical properties of technically most frequent gases up to temperatures of 6000 Kelvin are compiled.
From author's summary

2002. **Kooy, J. M. J., Thermodynamic theory of rocket motor with hydrazine and nitric acid as fuels,** *Astronaut. Acta* **1**, 4, 157–165, 1955.

In this paper, a thermodynamic theory of the rocket is developed, with hydrazine and nitric acid as fuels, taking into account the recombination of the molecules during the expansion of the gases in the nozzle. Equations are derived by which the concentrations in the expanding mixture can be found as functions of pressure and temperature, and the exhaust speed can be computed if the pressure in the combustion chamber is prescribed. From author's summary

2003. **Mel, H. C., Entropy production and the stationary state of chemical reactions,** *Acad. roy. Belgique, Bull. Cl. Sci.* **5**, 40, 834–845, Aug. 1954.

2004. **Brousseau, J. A., Jr., The optimum ratio of propellants for a liquid bipropellant rocket operating within a mixture ratio tolerance,** *Jet Propulsion* **26**, 2, 106–109 (Technical Notes), Feb. 1956.

For any liquid bipropellant rocket system designed for propellant exhaustion, close control of the burning mixture ratio and weight ratio of loaded propellants must be maintained if sizable quantities of unburned propellant are to be avoided at shutdown. This unused propellant reduces the total available impulse from the rocket, and a consequent reduction in the over-all performance of the flight article in which it is installed. This paper considers the problem of unburned propellant resulting from a bipropellant rocket operating over a range of mixture ratios. Equations are derived from a mathematical analysis which provides the rocket designer with tools for optimizing the weight ratio of propellants for any given operating mixture ratio tolerance. From author's summary

2005. **Barrére, M., and Moutet, A., Low-frequency combustion instability in bipropellant rocket motors—experimental study,** *Jet Propulsion* 26, 1, 9–19, Jan. 1956.

This interesting paper presents careful, systematic experiments on chugging rocket motors developed at the O. N. E. R. A. (France). After qualitive description of phenomena as observed from measurement of instantaneous chamber pressure and temperature and propellent flow rate, experimental equipment is described. It consists of a series of combustion chambers equipped with several injectors so that separation of effects of chamber pressure, characteristic length, pressure drops, nature of propellants, mixture ratio, and chamber size can be obtained. Oxydizer: nitric acid; fuel: furfuryl alcohol or octane. Quantitative results are presented in terms of observed frequencies, with qualitative statements about amplitude, and are compared with results of reviewer's theory, with good over-all agreement, since the experimental interaction index n is approximately independent of chamber shape, mixture ratio, pressure drop, and characteristic length. However, authors consider lack of agreement is due to its strong dependence on chamber pressure. Reviewer observes that, as specified in later publications, theory only requires that a value of n may be defined at each pressure, but does not exclude variations with pressure level. L. Crocco, USA

2006. **Li, T. Y., Stabilization of low-frequency oscillations of liquid propellant rockets with fuel line stabilizer,** *Jet Propulsion* **26**, 1, 26–33, 39, Jan. 1956.

Paper suggests use of two possible types of stabilizer for chugging rocket motors, capable of producing effects similar to those of increased pressure drop without pressure increase and without use of elaborate electronics; but only of simple, rugged mechanisms based on valves, pistons and springs. Both types introduce a variable restriction in feeding lines, controlled by instantaneous flow rate in first type and instantaneous time derivative of it in second. Systems are analyzed, including mechanical inertia, with the result that they may achieve desired purpose only if natural frequency of mechanisms is sufficiently high. Paper is interesting but difficult to read because of errors in equations and lack of care in presentation. L. Crocco, USA

2007. **Putnam, A. A., and Dennis, W. R., Suppression of burner oscillations by acoustical dampers,** *Trans. ASME* **77**, 6, 875–883, Aug. 1955.

Tests on the suppression of burner oscillations are described. The work was not all inclusive but did produce several positive conclusions which may help in quieting particular combustion installations, or may be of help in preventing waste of effort in trying ineffective methods. The effectiveness of a quarter-wave tube was found to be critically dependent on length, but relatively insensitive to location, as long as the tube is placed in the region of the pressure antinode. Similarly, the effectiveness of a Helmholtz resonator depended critically on volume for a particular neck, but is quite insensitive to location. In neither case did the suppressor have to be placed near the particular antinode where energy was fed into the oscillation. The degree of suppression obtained was approximately proportional to the cross-sectional area of the tube; the same conclusion appears to be warranted with regard to the cross-sectional area of the throat of a Helmholtz resonator. Almost complete suppression was obtained with holes drilled in the side of the tube and placed within 10% of a wave length from a pressure antinode. It was found that the diameter of the hole need not be greater than about 1/10 to 1/15 of the diameter of the combustion chamber, but should be greater than the wall thickness for best suppression. From authors' summary

2008. **Pchelkin, Yu. M., Working cycle studies of pulverized coal combustion chambers for gas turbomachines** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 8, 65–74, Aug. 1954.

2009. **Auble, C. M., and Heidmann, M. F., The application of radiation measurement techniques to the determination of gas temperatures in liquid propellant flames,** *J. Amer. Rocket Soc.* **25**, 9, part I, 449–453, 467, Sept. 1955.

Radiation temperature measurements have been made of a heptane-turpentine mixture burning with liquid oxygen in an open tube combustion chamber. Measurements were made by the two-color method at six stations along the tube. The temperatures obtained along the tube in this way were generally higher than the theoretical equilibrium flame temperatures or temperatures obtained with the sodium line reversal method. This difference at the various points is ascribed variously to gas temperature stratification, lack of thermodynamic equilibrium, or optical effects such as selective absorption or scattering. Considerable variations in temperature, radiation, and emissivity were found to exist at acoustical frequencies. The temperature given by the two-color method was found to fluctuate inversely with the radiation intensity. S. Silverman, USA

2010. **International Flame Research Committee, The radiation from turbulent jet diffusion flames of liquid fuel/coke-oven gas mixtures. 1. Purpose of the trials and practical implications of the results,** *J. Inst. Fuel* **29**, 180, 23–26, Jan. 1956.

In order to determine whether it is possible to make coke-oven-gas flames strongly luminous with small additions of liquid fuels (heavy fuel oil and creosote pitch), measurements have been made of the flame radiation (cold background) and flame emissivity at various points along the length of various flames. All the flames had the same total calorific input and the same length. It was found that the replacement of 20% of the gas with liquid fuel gives an increase in emissivity of 30% compared with that of a 100% liquid-fuel flame, which is four times that of a coke-oven-gas flame in the early part of the flame. On the other hand, 30% of creosote pitch or 20% of oil can be replaced by coke-oven gas without appreciable loss of emissivity compared with the 100% liquid-fuel flame. From authors' summary

2011. **Thring, M. W., The radiation from turbulent jet diffusion flames of liquid fuel/coke-oven gas mixtures. 2. Methods of increasing the emissivity of coke-oven-gas flames without addition of liquid fuels,** *J. Inst. Fuel* **29**, 180, 27–30, Jan. 1956.

The low emissivity of a turbulent coke-oven-gas flame is a serious obstacle to the achievement of a high heat-transfer rate from the flame. The emissivity can be increased by pure preheat of the gas, by slowing down the rate of air entrainment in the flame, and by preliminary partial combustion of the gas. The first and third of these methods are promising and require further investigation on an adequate scale. From author's summary

2012. Rivière, M., The radiation from turbulent jet diffusion flames of liquid fuel/coke-oven gas mixtures. 3. Conduct of the trials and their results, *J. Inst. Fuel* **29**, 180, 31-44, Jan. 1956.

A short description of the modification made to the experimental furnace in view of the use of gaseous fuels is followed by an account of the measurements taken during the performance trials. The variables under study during the three series of trials were fuel quantity, combustion-air quantity, jet-momentum quantity, fuel quality. The fuel was either coke-oven gas or a mixture in varying proportions of coke-oven gas and fuel oil or creosote pitch. The results show the influence of each of the variables on the flame radiation and the temperature of the walls, as well as the interactions between the variables.

From author's summary

2013. Greyson, M., Mazie, G. P., Myers, J. W., Corey, R. C., Graf, E. G., Evaluation of factors affecting heat transfer in furnaces, *Combustion* **27**, 8, 34-39, Feb. 1956.

Correlating the heat-absorption efficiencies of coal-burning equipment has been studied for many years with little more than a modicum of success. One of the major problems to such correlation has been the lack of precise furnace data. This paper describes the attempt at using statistics to correlate more reliable furnace data by means of the Broido, Hudson-Orrok, a modified Hudson-Orrok, Wohlenberg, and Hurvich correlations. Results suggest that information about flame temperatures, flame volumes, and emissivities and temperatures of flames and slag-ash-covered boiler-tube walls are necessary before precise correlations can be made.

From authors' summary

2014. Buna, T., Combustion calculations for multiple fuels, ASME Ann. Meet., Chicago, Ill., Nov. 1955. Pap. 55—A-185, 21 pp. + 7 figs., 2 tables.

Paper presents a detailed procedure for the calculation of the composite analysis and heat content of a plurality of fuels fired in combination, with special emphasis on the difficulties often encountered by the test and operating engineers in obtaining reliable fuel-flow data. The propagation of uncertainties in the basic quantities defining alternate efficiencies are discussed, and a procedure for the graphical representation of the CO_2-O_2-excess air relationship for dual fuels is developed.

From author's summary

Acoustics

(See also Revs. 1725, 1788, 1829, 2007, 2062)

2015. Binnie, A. M., and Miller, J. C. P., Tables of two functions required in certain attenuation problems, *Quart. J. Mech. appl. Math.* **8**, 4, 468-479, Dec. 1955.

Let $S(x,w) = (\exp\text{-}w)\,(w^2-x^2)^{1/2}$; $R(x,T) = S(x,T) + 2\int_x^T S(x,u)du$; $Q(x,T) = 2\int_x^T R(x,v)dv$. Paper tabulates R and Q to four or five significant figures for a wide range of values of x and T. Second differences in both x and T are provided for interpolation. Tables are useful for study of surges in flow along pipes [see AMR **5**, Rev. 455] and surges in electric transmission lines [see H. S. Carslaw and J. C. Jaeger, "Operational methods in applied mathematics," Oxford, 1941, p. 197]. Cited references should indicate possible application to other fields.

Y. L. Luke, USA

2016. Lane, C. A., Acoustical streaming in the vicinity of a sphere, *J. acoust. Soc. Amer.* **27**, 6, 1082-1086, Nov. 1955.

Author discusses steady streaming adjacent to a fixed sphere in an oscillating incompressible viscous fluid. Approximate theoretical results in series form are compared with experiments. No practical applications are indicated.

J. H. Huth, USA

2017. Blokhintsev, D. I., Acoustics of a nonhomogeneous moving medium, *NACA TM* 1399, iv + 194 pp., Feb. 1956. (Translation of "Akustika neodnorodnoi dvizhushcheisya sredy," Ogiz. Gosud. Izdat., Tekh.-Teor. Literatury, Moskva, 1946, Leningrad.)

Theoretical basis of the acoustics of a moving nonhomogeneous medium is considered in this report. Experiments that illustrate or confirm some of the theoretical explanation or derivation of these acoustics are also included.

From author's summary

2018. Young, J. E., Propagation of sound in thin elastic shells, *J. acoust. Soc. Amer.* **27**, 6, 1061-1064, Nov. 1955.

Author studies wave propagation in elastic cylindrical shell filled and surrounded by air and compares dispersion predicted by wave-theoretical and lumped-constants analyses.

M. C. Junger, USA

2019. Carrier, G. F., Sound transmission from a tube with flow, *Quart. appl. Math.* **13**, 4, 457-461, Jan. 1956.

Author considers radiation of a sound wave from an open-ended circular tube when a mean flow is superimposed on sound wave. Solution obtained is by means of an extension of the work of Schwinger and Levine, who treated case with no flow. This extension is similar to Prandtl-Glauert method in subsonic aerodynamics. Result given by author is in form of a reflection coefficient for sound wave.

O. K. Mawardi, USA

2020. Karas, K., and Ahbe, H., Analytical investigation of the striking process on a string instrument (in German), *ZAMM* **35**, 11, 406-427, Nov. 1955.

Literature on accoustics of string instruments does not contain thorough and satisfactory investigation of complicated mechanical process beginning with the impact of a compressible hammer (hammer with felt). In this paper, the striking process is examined on the basis of an empirical law of statical deformation of the hammer, using fundamental equations of mechanics, a method originated by S. Timoshenko. Lagrange equations are used, and the authors, with reference to previous work of C. Schmieden, H. Weirich, R. Klaus, R. E. Horton, K. Knopp, F. Auerbach, and K. W. Wagner, arrive, under the assumption of fixed string ends, at the following conclusions: (1) Compressive force of the hammer exerted at the center of string can show considerable variations independent from transient waves of the string. (2) Hysteresis of the hammer felt is of decisive importance for the generation of the tone. (3) Rotatory inertness of the string elements has no appreciable influence on striking process when the dimensions of piano chords are limited as usual.

J. J. Polivka, USA

2021. Friedrichs, K. O., and Keller, J. B., Geometrical acoustics. II. Diffraction, reflection, and refraction of a weak spherical or cylindrical shock at a plane interface, *J. appl. Phys.* **26**, 8, 961-966, Aug. 1955.

Authors apply the method described in part I [AMR **9**, Rev. 321] to the reflection and refraction of a spherical or cylindrical acoustic pulse at a plane interface between two media and at a plane slab separating two media. In particular, they investigate the discontinuity across the "bow wave" (the "diffracted shock") which appears in the medium with the smaller sound speed when the disturbance originates in it, obtaining, in a simple way, results quite difficult to extract from the Fourier series approach.

F. J. Berry, England

2022. Parolini, G., On sound absorption by cylindrical diffusers, *J. acoust. Soc. Amer.* **26**, 5, 795-797, Sept. 1954.

A more efficient use of acoustic materials of porous type is made by applying them not directly on the wall but by concentrating them on small-volume plywood cylindrical absorbers (diam up to 50 cm, glass-wool coating of 20-mm thickness and 60 kg/m³ specific gravity). High absorption was obtained even in the low frequency range, due to the resonance of the cylindrical plywood frame. Experimental results are also given for cylinders made of faesite, with holes or rectangular slots and lined or filled with glass wool. A comparison with theoretical results is given.

J. Meixner, USA

2023. Rao, C. R., Sound absorption coefficients based on intensity measurements of diffraction orders, *Proc. Indian Acad. Sci. (A)* **42**, 6, 331-335, Dec. 1955.

2024. Embleton, T. F. W., Mean force on a sphere in a spherical sound field. I. Theoretical; II. Experimental, *J. acoust. Soc. Amer.* **26**, 1, 40-50, Jan. 1954.

The mean force on a freely suspended rigid sphere of radius a placed

distance r from point source of sound, wave number k, is calculated by standard Legendre polynomial analysis in terms of parameters kr and ka. For large r, force is inverse square repulsive. For small r, force is attractive. Experimental data are presented which give good quantitative check on theory. B. Noble, Scotland

2025. **Chernov, L. A., Sound propagation in a statistically inhomogeneous medium** (in Russian), *Zh. eksp. teor. Fiz.* **24**, 2, 210–213, 1953 (translation by R. Bowman; available from M. D. Friedman, 572 California St., Newtonville, Mass. 7 pp.).

Chernov obtains typical mean square derivations of a ray from its original direction from usual differential equation for angular distribution functions of rays in a medium with random inhomogeneities. The paper covers several routine derivations and it is surprising that this work was published. K. M. Siegel, USA

2026. **Cook, R. K., Waterhouse, R. V., Berendt, R. D., Edelman, S., and Thompson, M. C., Jr., Measurement of correlation coefficients in reverberant sound fields,** *J. acoust. Soc. Amer.* **27**, 6, 1072–1077, Nov. 1955.

Method is described for testing sound fields in reverberation rooms for randomness by comparing experimentally measured cross-correlation coefficients with those obtained theoretically. Experimental techniques are discussed and example results of measurements in reverberant sound fields are given. J. M. Hedgepeth, USA

2027. **Dawance, G., and Chefdeville, M., J., Acoustic measurements on concrete. New methods for the determination of the quality of concrete through sound velocity measurements. Part I. Apparati for sound velocity measurement in concrete and sound propagation in concrete** (in German), *Schweiz. Arch.* **21**, 7, 223–234, July 1955.

Authors, Chief Engineers of Laboratoire du Bâtiment et des Travaux Public (Paris), consider the dynamic modulus of elasticity E and Poisson's constant as applied to concrete. The equipment available for the determination of E with the help of vibrations in the sonic range (1500 to 12,000 ops) is described in considerable detail. Typical records facilitate appreciation of methods and results, vibration excitation being by mechanical impact or use of small explosive charges. Results based on tests on old concrete suggest that a longitudinal sound velocity of less than 2130 m/sec indicates very poor quality, 2130 to 3040 poor, 3040 to 3650 average, 3650 to 4560 good, and over 4560 m/sec very good quality. Numerous graphs illustrate typical dependencies and stimulate interest in a development of considerable interest to practicing engineers. J. L. Koffman, England

2028. **Dawance, G., and Chefdeville, M. J., Acoustic measurements on concrete. New methods for the determination of the quality of concrete through sound velocity measurements. Part II. Investigations on the applicability of sound velocity measurements in concrete** (in German), *Schweiz. Arch.* **21**, 10, 313–325, Oct. 1955.

The application of sound velocity measurements for the determination of concrete properties dealt with in preceding review is considered further on the basis of results of numerous tests. These comprise dynamic modulus of elasticity E as affected by aging in air and water, prestressing, aging of various concrete types, frost, corrosion, and fire. Also, effects on contraction and modulus of aging and corrosion. Relation between E and strength in compression and tension. Both papers are written clearly and lucidly and provide powerful stimulus for further work in this field. J. L. Koffman, England

2029. **Deo, B. B., Ultrasonic absorption in solutions,** *Indian J. Phys.* **38**, 7, 352–356, July 1955.

Paper extends the results of Freedman [*J. chem. Phys.* **21**, p. 1784, 1953] on the ultrasonic absorption of sound waves in solutions by considering modifications occurring when the chemical reactions are accompanied by both changes in volume and in temperature. Additional relaxations occur which depend on the change in volumes ΔV and the reaction rates of dissociation. It is suggested that one of the two relaxations found in magnesium sulphate ($MnSO_4$) in water is due to the production of an ion pair, while the other is due to a change in volume relaxation. Enough experimental data is not available to verify the assumption. W. P. Mason, USA

2030. **Ozdogan, B., Experimental determination of pressure caused by ultrasonic waves exerted on bodies** (in French), *J. Phys. Radium* **16**, 12, 902–907, Dec. 1955.

2031. **Eyraud, C., Separative effect of ultrasound on a gaseous mixture** (in French), *C. R. Acad. Sci. Paris* **242**, 4, 474–475, Jan. 1956.

2032. **Chase, C. E., Ultrasonic propagation in liquid helium,** *Amer. J. Phys.* **24**, 3, 136–155, Mar. 1956.

A series of measurements of the propagation of sound in liquid helium is described, and the results discussed in terms of various aspects of the theory of liquid helium. Measurements of the velocity were first made at 14.2 mc/sec over the temperature range from the normal boiling point down to 1.2 K, with particular attention to the low-temperature region and the neighborhood of the λ point. The attenuation was later measured at 2.0, 6.0, and 12.1 mc/sec, and the measurements were extended down to 0.85 K. A few velocity measurements were also made at these frequencies. Finally, the 12.1 mc/sec results were extended down to 0.1 K by the technique of adiabatic demagnetization. The attenuation in helium II is anomalously high and passes through two closely spaced maxima a little below 1 K, finally falling smoothly toward zero at the absolute zero. No adequate theoretical explanation for this behavior exists, although above 1 K the high attenuation has been explained qualitatively. Near the λ point the attenuation rises to another very sharp maximum and the velocity passes through a minimum. This behavior sheds some light on the nature of the λ transition. The first part of this paper is devoted to a brief review of relevant experimental and theoretical aspects of the liquid helium problem.

From author's summary

2033. **Mirels, H., Acoustic analysis of ram-jet buzz,** *NACA TN* 3574, 33 pp., Nov. 1955.

A one-dimensional analysis of ramjet buzz is made by investigating a particular mechanism for buzz, namely, the amplification of acoustic waves in the ramjet combustion chamber due to successive reflections from the inlet and exit sections.

It is assumed that the combustion chamber is of constant area, that it is long compared with the length of the inlet, and that the exit always operates quasi-steadily. The inlet operates quasi-steadily, or nearly so, during unsteady operation. The configuration is shown to be unstable when the real part of the acoustic impedance of the inlet is greater than a term of the order of the combustion-chamber Mach number. For quasi-steady operation, the impedance of an inlet is proportional to the slope of its characteristic curve. Increasing the combustion-chamber Mach number or decreasing the slope of the inlet characteristic curve during subcritical operation tends to increase the range of stable operation.

Computations made on the assumptions that the flame front is fixed and plane and that the heat release per unit mass is constant indicate that burning increases the stable operating range of a given configuration. From author's summary by N. Tetervin, USA

2034. **Callaghan, E. E., and Coles, W. D., Investigation of far noise field of jets. I. Effect of nozzle shape,** *NACA TN* 3590, 44 pp., Jan. 1956.

The noise generation of jets discharging from convergent (circular, square, rectangular, and elliptical), plug, and convergent-divergent nozzles was investigated. At low jet pressure ratios (less than 2.2) all the nozzles had approximately the same sound field. At high pressure ratios, all the nozzles produced noise having discrete-frequency peaks. Only the convergent-divergent nozzle showed a reduction in both amplitude of the discrete-frequency noise and in total sound power radiated as compared with ordinary convergent nozzles.

From authors' summary

2035. **Coles, W. D., and Callaghan, E. E., Investigation of far noise field of jets. II. Comparison of air jets and jet engines,** *NACA TN* 3591, 19 pp., Jan. 1956.

A comparison of the noise generation of air jets and turbojet engines was made from data obtained from similar free-field surveys. At jet pressure ratios below or only slightly above that for choked flow, the over-all sound power was well represented by the Lighthill parameter,

but the sound-power results obtained during afterburner operation were somewhat low. Directional patterns for over-all sound pressures were similar for the engines and air jets. Air-jet and engine spectral data were dissimilar because of a dip in the engine-noise spectrum.

From authors' summary

2036. Mace, W. D., Haney, F. J., and Brummer, E. A., Instrumentation for measurement of free-space sound pressure in the immediate vicinity of a propeller in flight, *NACA TN* 3534, 16 pp., Jan. 1956.

Instrumentation suitable for the measuring, recording, and subsequent harmonic analysis of the free-space sound pressures in the immediate vicinity of an airplane propeller at flight Mach numbers up to 0.72 is described. The dynamic range of the equipment is 150 to 113 decibels (re 0.0002 dyne/cm^2) and the system frequency response is flat within ± 1 decibel from 80 to 1000 cps. Maximum second-harmonic distortion is less than 3% for a sound level of 140 decibels, and the over-all accuracy is ± 2 decibels. From authors' summary

2037. North, W. J., Effect of climb technique on jet-transport noise, *NACA TN* 3582, 19 pp., Jan. 1956.

A theoretical investigation of jet-transport climb technique was made to determine the effect of variations in engine thrust and airspeed on sound-pressure levels heard by a ground observer. Reduced noise levels will be obtained when climbing on the steepest flight path consistent with minimum safe airspeed. Additional noise reduction may be obtained by throttling the engine; however, the additional benefit accompanying permissible thrust reduction is small.

From author's summary

2038. Whitmore, J. M., Lull, W. R., and Adams, M. D., How sound affects vibration in modern aircraft engines, *GM Engng. J.* **2**, 6, 2-8, Nov.-Dec. 1955.

Ballistics, Detonics (Explosions)

(See also Revs. 2002, 2004)

2039. Tits, E., The detonation of gaseous mixtures (in French), *Explosifs* **8**, 3, 93-98, July-Sept. 1955.

A method for calculating detonation in gaseous mixtures is described which consists of (1) calculating the equilibrium composition of the products at a number of assumed temperatures, and (2) finding the correct temperature by plotting a balance of heat of reaction, internal energy of the product gases, and kinetic energy.

Calculation of the equilibrium composition entails solving a large number of simultaneous equations, which is done by a graphical method due to Damkohler and Edse [*Z. Electrochem.* 178-86, 1943]. The detonation of a stoichiometric acetylene-air mixture is worked out in detail. W. Squire, USA

2040. Heitkotter, R. H., The design of a miniature solid-propellant rocket, *NACA TN* 3620, 13 pp., Mar. 1956.

A miniature rocket motor was designed and developed to produce three ounces of thrust for a duration of two seconds. The rocket is simply designed, safe to operate, easily handled, and gives reproducible performance. Standard solid-propellant-rocket design techniques were found to be not wholly applicable to the design of miniature rockets because of excessive heat losses. From author's summary

2041. Vogel, J. M., A quasi-morphological approach to the geometry of charges for solid propellant rockets: the family tree of charge designs, *Jet Propulsion* **26**, 2, 102-105 (Technical Notes), Feb. 1956.

One of the principal areas in the design of any solid propellant rocket is the selection of a suitable geometry for the propellant charge. A morphological classification of charge designs is developed, based upon their several distinguishing characteristics. From the classification so developed it appears that at least 6240 charge designs are available, many of which are, of course, impractical for various reasons. Using the morphological classification as a datum, a quasi-morphological approach is discussed which seems to be peculiarly well adapted to the particular field of charge design. It is shown that a family tree interrelating charge configurations can be established by inventing or identifying a means of compensating for some undesirable feature of a chosen design, extending the principle (i.e., introducing redundancy), or inverting the principle. From author's summary

2042. Tinè, G., Some considerations on propellant mass flow in a flying missile (in Italian), *Aerotecnica* **35**, 5, 260-266, Oct. 1955.

The influence of an acceleration and a variable tank hydraulic head on the value of the propellant mass flow of a gas-pressure-fed missile is analyzed. Then the developed method of calculation is applied to a practical case of a two-propellant missile.

From author's summary

Soil Mechanics, Seepage

(See also Revs. 1743, 1976)

2043. Shchelkachev, V. N., Simplification of solutions of Fourier differential equations for problems on circular groups of wells and drains (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **101**, 2, 225-228, 1955.

Theoretical presentation of the pressure conditions in wells and drain holes with consideration of the underground hydrodynamics. Solution is carried out on the basis of analogical conditions of heat-conduction and diffusion problems by Fourier differential equations.

J. J. Polivka, USA

2044. Frölich, O. K., On a simple application of the potential theory for the calculation of the tilting of structures, *Anz. Akad. Wiss. Wien* **89**, 1, 47-53, Jan. 1952.

The known formulas for the tilting of a circular and of a continuous footing under the action of a moment are derived for a purely elastic soil in the simplest possible way, utilizing Boussinesq's elastic potential. H. Lundgren, Denmark

2045. Campbell, J. E., and Heaps, H. S., Transmission of stress through a thick slab supported by a yielding foundation, *Canad. J. Technol.* **33**, 5, 324-334, Sept. 1955.

Paper presents closed solutions of stresses and displacements for general problem of unilateral load applied to an infinite elastic slab of finite thickness supported by a perfectly discontinuous elastic medium. Analysis is direct and solutions are provided with tables for facilitating computations. Stresses are shown graphically for special cases of surface loads distributed uniformly over a line or over a half plane. Results are shown dependent upon foundation modulus k, defined for a discontinuous medium as the vertical stress at any place necessary to produce a unit displacement at the point of application. Procedures given in paper should be quite valuable in dealing with more complicated cases using the methods of superposition.

J. M. DallaValle, USA

2046. Rollins, R. L., Spangler, M. G., and Kirkham, D., Movement of soil moisture under a thermal gradient, *Nat. Res. Counc. Highway Res. Bd. Proc.* **33**, 492-508, 1954.

There is need of improvement in the understanding of soil moisture movement under a thermal gradient. The problem is of importance in, e.g., road construction, heat pump operation, and dissipation of heat from buried electrical cables.

Authors present a theoretical and experimental investigation of the problem together with a review of previous literature. They consider the movement to be caused by vapor transfer under the influence of a temperature-induced vapor pressure gradient and by liquid movement due to capillary forces.

In their experiments, horizontal soil columns are subjected to a temperature gradient for several days. Comparisons are made between closed columns and columns in which liquid water can recirculate through a 2-mm capillary tube connecting the warm and the cold side. Movement in this tube is from cold to warm; the flow rate is measured after reaching a constant value. Results are given for a silty loam and

a sand, with the former at different dry densities and temperature gradients. At the end of each experiment the moisture content was gradually increasing from warm to cold in the closed columns, but was fairly constant in the circulating systems with a slight lowering at each end, which was most pronounced at the warm side.

Authors argue that movement in the circulating system is due to vapor movement only. The measured flow rate appears to be about six times the rate computed on a basis of molecular diffusion of water vapor through the air-filled pores.

Although reviewer agrees with the conclusion that movement in the soils of the circulating systems is mainly in the vapor phase (he thinks that there may be an additional slight liquid movement from cold to warm), he believes that authors' reasoning leading to this conclusion is partly incorrect. This applies in particular to the argument on p. 499 re Fig. 3.

D. A. de Vries, Australia

2047. **Shablia, V. N., Observations and some conclusions on deposits around large hydraulic engineering structures erected on compressible soils** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 10, 161-170, Oct. 1954.

Micromeritics

(See also Revs. 1996, 2046)

2048. **Weidner, G., Basic investigation into pneumatic conveying with special regard to the conditions during acceleration and in elbows** (in German), *Forsch. Geb. Ing.-Wes.* **21**, 5, 145-153, 1955.

The total pressure drop experienced during the pneumatic conveying of granular materials through ducts consists of friction plus acceleration pressure drop, and, in case of vertical transport, also of a "hydrostatic" pressure drop. The paper gives a theoretical analysis based essentially upon single-particle flow characteristics and a simplified mechanism with the object of clarifying the actual complex phenomena. In particular, the phenomena in acceleration zones and in bends of the duct are considered. Satisfactory agreement is claimed with the few experimental results considered.

Though the author realizes that the dynamics of a concentrated group of particles is different from that of a single particle, he assumes that such a difference is only quantitative. In this respect reviewer believes that this assumption is too optimistic, and that the mechanism described is too simple. It might be applicable to cases of transport through small-diameter pipes and at low solids loadings (low concentration) but certainly not to cases of high loadings and large-diameter pipes.

J. O. Hinze, Holland

2049. **Klemperer, H., and Sayers, J. E., Design aspects of an electrostatic precipitator for the collection of small solids ahead of the air heater**, *Trans. ASME* **78**, 2, 317-326, Feb. 1956.

The development of a novel electrostatic precipitator is described which operates in the temperature range between 500 and 750 F, at a gas velocity of 40 fps. The precipitator consists of twelve independent sectors, arranged in rotary symmetry. A stream of cleaning gas is continuously moving from one sector to the other to carry the deposited dust into a secondary cyclone-type collector. Each sector is connected to an individual power supply, controlled on the primary side by a system of saturable reactors. Design viewpoints are given that lead to the described system. A commercially sized test plant is described that is operated on a 150,000 lb of steam per hr pulverized-fuel-fired boiler, consisting of a mechanical precollector followed by the precipitator ahead of the regenerative-type air preheater. The efficiency of the electrostatic precipitator alone is of the order of 95%.

From authors' summary

Geophysics, Meteorology, Oceanography

2050. **Carter, J. T., and Stickel, J. F., Geophysics as a tool in soil mechanics**, *Civ. Engng. N.Y.* **25**, 10, 58-61, Oct. 1955.

2051. **Charnock, H., Statistics and aerodynamics of the sea surface**, *Nature* **177**, 4498, 62-63, Jan. 1956.

2052. **Hawthorne, W. R., and Martin, M. E., The effect of density gradient and shear on the flow over a hemisphere**, *Proc. roy. Soc. Lond. (A)* **232**, 1189, 184-195, Oct. 1955.

This paper studies the flow over a hemispherical hump in connection with the study of the flow over a hill standing in flat surroundings. In this calculation, the uniform flow is assumed to have (1) constant static pressure, (2) varying velocity and density with height. To estimate the velocity field behind a hill, the fundamental equation of motion for inviscid fluid which contains the gravitational force term is solved by perturbation method. The calculation is limited mainly to the following two cases: (1) the density gradient in the flow exists and, far downstream, the static pressure of the flow becomes zero; (2) both the dynamic pressure gradient and the density gradient of the flow exist. As in the case of boundary-layer problem dealing with the flow over a riveted airfoil, the former case results in the occurrence of the horseshoe vortexes on the base of hemisphere. In the latter case, which corresponds to the meteorological phenomena observed in the flow of air over a hill or a mountain, the fact that the wind with an unstable lapse rate over a hill would cause an upward stream in the upper region and a downward stream near the bottom is suggested. To verify these theoretical considerations, a very low-speed tunnel was utilized for the experiment, and the flow pattern of air over a hemisphere placed on hot plate was investigated by means of lubricating oil smoke. The experimental results were found to agree with the theoretical predictions.

The present reviewer appreciates this meteorological line of study and the interesting suggestions for basic research of a boundary-layer flow over a surface roughness. Valuable experimental suggestions for the problem of heat transfer through rough surfaces are also given.

T. Okamoto, Japan

2053. **Seneca, J., Measurement of turbulent diffusivity with smoke puffs** (in French), *J. sci. Météor.* **7**, 26, 221-225, Apr.-June 1955.

A balloon is used to carry aloft five 50-cc ampules of titanium tetrachloride, each of which is dispersed by a five-gram powder charge fired electrically to form a puff of smoke. The dispersion of these puffs at various levels between heights of 100 and 1000 m is recorded by a cinecamera with telephoto lens.

Assuming homogeneous and isotropic diffusion, a simple expression is established for the diffusivity b in terms of the puff growth. Account is taken of initial disturbance caused by the explosion lasting 20-30 secs; then follows a phase of normal growth (during which diffusivity observations are made), and, finally, puff disperses. Puff size is found to depend on atmospheric conditions.

For each puff an average value of diffusivity is calculated which shows a slight increase with altitude. Comparison with radiosonde information shows no apparent relationship between stability and diffusion, which is surprising. No comparisons are made with other work in this field.

Author admits limited value of conclusions drawn from comparatively few observations, with which reviewer agrees. With further development, the method appears attractive.

R. Culver, Australia

2054. **Thom, H. C. S., Frequency of maximum wind speeds**, *Proc. Amer. Soc. civ. Engrs.* **80**, Separ. no. 539, 1-11, Nov. 1954.

As it is well recognized that high wind speeds cannot be fully predicted from physical analysis alone, statistical analysis of climatological series of wind data is used by the Weather Bureau for determining design wind speeds. In this paper, only these climatological aspects of the problem are treated. The design wind speed is based on probability statistics by choosing a suitable function of the wind-speed observations to standard and arbitrary heights above ground. The power law $V_z = V_0(z/z_0)^{1/n}$ is given (V_0 is speed at the height z_0, V_z at the height z) with a constant average value for n of about 7. For the distribution of annual extreme wind speed, the mathematical statisticians Fisher and Tippett have derived three types of functions: (I) $F(x) = \exp(-e^{-x})$; (II) $F(x = \exp(-x^{-\gamma})$; (III) $\exp(-[-x]^{\gamma})$ if $F(x)$ is the propability of a value being less than a normalized variable x. A method of fitting the Fisher-Tippett Type II distribution to standardized

series is developed and applied to series for Fort Wayne. Also a probability paper for this distribution is developed and applied in the fitting of the distribution. M. Schäfer, Germany

2055. Walker, W. G., Gust-load airspeed data from one type of two-engine airplane on six civil airline routes from 1947 to 1955, *NACA TN* 3621, 25 pp., Feb. 1956.

Approximately 70,000 hr of V-G data from one type of two-engine transport airplane were analyzed to determine the severity and frequency of occurrence of the gust loads and gusts. The data were obtained during routine feeder-line and short-haul commercial operations on six different routes from 1947 to 1955. The results obtained indicate that normal accelerations corresponding to the calculated value of limit-gust-load-factor increment may be exceeded, on the average, twice (once positive and once negative) within the range of 3.6×10^6 to 106.0×10^6 flight miles for the various operations. A derived gust velocity of 50 fps may be exceeded twice within the range of 0.8×10^6 to 23.5×10^6 flight miles. There were sizable variations among the different operations with regard to the loads, gust velocities, and operating airspeeds, but, in general, these quantities were of the same order of magnitude as those experienced in past operations of the same type of airplane. From author's summary

2056. Hacker, P. T., An oil-stream photomicrographic aeroscope for obtaining cloud liquid-water content and droplet size distributions in flight, *NACA TN* 3592, 36 pp., Jan. 1956.

A small aperture in the front of a small-sized collector permits water droplets to impinge on a moving stream of oil. The oil flows then to a suitably designed channel constructed of transparent material so that the layer of oil is sufficiently thin to be photographed with a microscope and insure that the droplets are in focus. Experiments demonstrate that the water drops do not mix and that the water can be separated from the oil and the oil circulated continuously. Data obtained with the aeroscope are in general agreement with measurements made by other means. M. Tribus, USA

2057. White, R. M., and Galligan, A. M., The comparative accuracy of certain statistical and synoptic forecasting techniques, *Bull. Amer. meteor. Soc.* **37**, 1, 1-7, Jan. 1956.

Forecasts of the pressure-height variations at eight stations in the eastern United States are prepared by a statistical technique employing empirical influence functions. The accuracy of such forecasts is found to be comparable with that attained by synoptic techniques.

From authors' summary

Lubrication; Bearings; Wear

(See also Revs. 1697, 1951)

Book—2058. Slaymaker, R. R., Bearing lubrication analysis, New York, John Wiley & Sons, Inc., 1955, xiv + 108 pp. $5.

The purpose of this book appears to be to present the basic principles of bearing lubrication in a manner sufficiently simple to be easily understandable and at the same time useful to engineers and designers.

In general, the author has done this admirably. In simple steps are explained the physics of viscosity, the theory of its measurement, and the application of this theory to practice. The mathematics of hydrodynamic journal bearing lubrication is developed excellently, with many appropriate examples of its application. This treatment in general will be found adequate and useful and is, together with the chapter on examples of sleeve bearing design, the most valuable portion of the book.

The remainder of the book is devoted to the mechanical and metallurgical features of bearing design together with some discussion of oiliness, polar compounds, oilless bearings, etc.

This reviewer would commend this book for its good development of elementary theory and its practical application to bearing design.

On the other hand, it is felt that some features could have been given fuller treatment with considerable benefit. For example, due to its present wide spread use, the Fenske viscosimeter deserves considerable discussion, and, similarly, the discussion of viscosity index appeared to be inadequate. In the development of the hydrodynamic theory, the most interesting and instructive proof concerning the relative torque of the shaft and its bearing was omitted. Another omission which perhaps is more serious is a discussion of oil film whirl, which is a factor assuming some importance in high-speed bearings. R. Best, USA

2059. Osterle, F., Charnes, A., and Saibel, E., On the solution of the Reynolds equation for slider-bearing lubrication—IX. The stepped slider with adiabatic lubricant flow, *Trans. ASME* **77**, 8, 1185-1187, Nov. 1955.

2060. Lancaster, J. K., Surface film formation and lubrication, *Research* **8**, 7 (supplement), s33-s35, July 1955.

Experiments are described in which a 3/8-in. diam sphere was reciprocated over tin base white metal under a load of 2 kilogrammes. Contact potential drop between the sliding surfaces was measured. These experiments were similar to those of Lunn excepting that in this case sliding speed was varied over the range 15 cm/sec to 90 cm/sec at the center of the stroke. Both chromium plated and 0.4% carbon-steel spheres were used, together with a wider range of lubricants varying from cetane to silicone fluids containing various additives. A general tendency for contact resistance to increase rapidly when the product of speed and viscosity exceeded ten poise cm/sec is reported. The author suggests that, because Lunn's tests were carried out at a higher value than this, he was, in fact, reporting the establishment of a hydrodynamic film rather than the formation of a solid surface film. He supports, however, the postulate that the greater the tendency for a given metal-lubricant combination to form a protective solid surface film, the more easily may hydrodynamic lubrication be achieved.

F. T. Barwell, Scotland

2061. Rabinowicz, E., The friction of boundary-lubricated surfaces, *Proc. second U. S. nat. Congr. appl. Mech.*, June 1954; Amer. Soc. mech. Engrs., 1955, 595-599.

This paper discusses several different methods, based on friction and metal-transfer measurements, of determining the relative importance during the sliding of lubricated surfaces of the shearing of the lubricant layer and of the penetration of the lubricant with the formation of welded junctions. An extension of these methods suggests that the total friction force is the linear sum of the two separate components due to the lubricant layer and the metal junctions. In consequence, fresh light is thrown on the stick-slip phenomenon and its prevention by the use of good boundary lubricants.

From author's summary by H. T. Corten, USA

2062. Newkirk, B. L., Varieties of shaft disturbances due to fluid films in journal bearings, Second Ann. ASLE-ASME Conf., Indianapolis, Ind., Oct. 1955. Pap. 55-LUB-12, 5 pp. + 4 figs.

The disturbances heretofore called "shaft whipping," "oil whip," or "oil-film whirl" have been recognized and discussed for some 30 years. Recently, interest has become active and certain apparent inconsistencies of reported behavior have come to light. For example, the disturbance appears with some rotors that run at speeds below their lowest critical speeds and, in other cases, it does not appear unless the rotor runs at more than twice its lowest critical speed. In the field, some rotors exhibiting the disturbance can be quieted by warming up the oil supplied to the bearing, and in other cases, cooling the oil supply is effective. There are other diversities of behavior which are discussed in the paper that indicate a complex situation requiring clarification.

From author's summary

2063. Nemeth, Z. N., and Anderson, W. J., Effect of oxygen concentration in atmosphere on oil lubrication of high-temperature ball bearings, Second Ann. ASLE-ASME Conf., Indianapolis, Inc., Oct. 1955. Pap. 55-LUB-8, 6 pp. + 4 figs.

Studies were made of ball bearings operated at bearing temperatures to 850 F and lubricated with grade 1010 turbine oil with the ambient atmosphere consisting of air-nitrogen mixtures of various ratios. The results show that a 20-mm-bore ball bearing will run at temperatures to 850 F with oil lubrication if the oil flow exceeds a critical amount, believed to be equal to that which is removed by evaporation, thermal decomposition, and oxidation. Oxidation of the oil was controlled by regulating the amounts of oxygen and nitrogen in the atmosphere surrounding the test bearing. From authors' summary

2064. **Murray, S. F., Johnson, R. L., and Swikert, M. A., Difluorodichloromethane as a boundary lubricant for steel and other metals,** Second Ann. ASLE-ASME Conf., Indianapolis, Ind., Oct. 1955. Pap. 55—LUB-2, 5 pp. + 3 tables, 2 figs.

A study was made of difluorodichloromethane as a boundary lubricant for steel or other metals sliding against steel. Difluorodichloromethane was most effective in lubricating steel surfaces when both specimens were of similar hardness. Modified H-monel sliding on hardened tool steel was one of the more effective metal combinations for lubrication with difluorodichloromethane. The method and conditions of application are very critical in lubrication by gaseous materials. Further research data are necessary in order to specify means for assuring successful gaseous lubrication in practical mechanisms.

From authors' summary

2065. **Bondi, A., and Diamond, H., Physico-chemical investigation of engine oil performance,** Second Ann. ASME-ASLE Conf., Indianapolis, Ind., Oct. 1955. Pap. 55-LUB-5, 10 pp. + figs.

2066. **Crump, R. E., Solid-film lubricants,** *Prod. Engng.* **27**, 2, 200-205, Feb. 1956.

2067. **Tourret, R., Worm-gear lubrication. Effect of oil viscosity on power losses and wear,** *Engineering* **180**, 4692, 888-891, Dec. 1955.

Marine Engineering Problems

(See also Rev. 1802)

2068. **Herfst, L. P., Approximation method for the determination of the influence of free fluid surfaces on ship stability at large angles of inclination** (in Dutch), *Schip en Werf* **23**, 3, 53-58, Feb. 1956.

Many tanks containing fluid with a free surface can be approximated by tanks of rectangular section. Calculations for such tanks have been carried out for angles of inclination α of 10, 20, 30, 90 deg of the decrease of the arm of statical stability by the use of an expression $c \cdot i \cdot \gamma$, where i is the moment of inertia of the rectangular section of the tank, γ the specific mass of the fluid, and c a constant. This constant is presented in graphs for various α, using h/b and t/h as parameters, where h is height, b width of the tank, and t height of level of the fluid. For tanks of more trapezoid form, graphs of form coefficients and moments of inertia are presented.

An example of calculation for a trawler is given at the end of the article.

Since the basic stability equations used are those for large angles of inclination, this work represents a definite improvement on the work of E. Danckwardt [*Schiffbautechnik* May 1955], who uses expressions of initial stability for large angles of inclination.

L. Troost, USA

2069. **Krohn, J., Examination of velocity-distribution in an experiment-tank with flowing water,** *Inter. Shipbldg. Progr.* **2**, 16, 559-566, 1955.

A description is given of a testing facility at Duisburg, Germany for model tests on river boats. Particular features are adjustable flow velocity, by a controllable-pitch propeller pump, controllable depth, and a control of velocity distribution by use of guide vanes. Plots of typical velocity distributions are given.

F. E. Reed, USA

2070. **Mandelli, A., Simplified calculation of longitudinal bending moments,** *Trans. Instn. Engrs. Shipb. Scot.* **99**, 4, 265-288, 1955/56.

The paper is divided into three parts. The first describes a method by which the exact value of the bending moment amidships for any condition of loading of a given ship can be calculated without resorting to bending-moment curves. The second deals with the determination of the influence line of bending moment amidships and its practical applications. The third part gives a method by which the basic calculations of part I can also be used to determine the buoyancy curve when a complete bending-moment curve is required.

From author's summary

2071. **Van Aken, J. A., and Tasseron, K., Comparison between the open-water efficiency and thrust of the "Lipsschelde" controllable-pitch propeller and those of "Troost"-series propellers,** *Inter. Shipbldg. Progr.* **2**, 1, 30-40, 1955.

2072. **Remez, Yu. V., and Khaskind, M. I., Calculating the speed and motion of ships** (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 12, 132-133, Dec. 1954.

2073. **Okabe, T., Hirata, K., and Kumai, T., Vibration measurements of 32,000 ton D. W. super tanker,** *Rep. Res. Inst. appl. Mech.* **4**, 13, 13-21, July 1955.

Measurements in the frequency range up to about 400 cpm and up to nine nodes are reported.

K. Klotter, USA

Letters to the Editor

2074. **Re AMR 8, Rev. 2488 (August 1955): Darpas, M. J., Investigation of tunnel testing of projectile models at supersonic velocities.**

Third sentence in the review should read "Geometric characteristics investigated are ogive curvature and taper, body and base shape and size, and presence of rotating band" instead of "... are to give curvature...." The editors regret this error.

2075. **Re AMR 8, Rev. 3332 (November 1955): Narasimhamurthy, P., Torsion of multiply connected sections.**

The equality sign in the inequality (2) of the above paper is valid only when the contour of the inner hole coincides with a ϕ – line. Thus it is true, as the reviewer pointed out, that the method *is exact* only when the inner and outer boundaries are concentric circles. But the present method is suggested to give *approximate values of ϕ on centrally situated small circular and nearly circular holes.* In such cases the outer boundary can be general. The method gives satisfactory numerical results because the examples considered satisfy the above condition on the nature of holes. In fact, the hole in the splined shaft is neither circular nor nearly circular; still a satisfactory approximate value is obtained, as compared with the exact value.

P. Narasimhamurthy, India

Books Received for Review

BATCHELOR, G. K., AND DAVIES, R. M., editors, Surveys in mechanics (The G. I. Taylor 70th Anniversary Volume) (Cambridge Monographs on Mechanics and Applied Mathematics), New York, Cambridge University Press; Cambridge, England, The University Press, 1956, 475 pp. $9.50.

CAMPBELL, I. E., editor, High-temperature technology (The Electrochemical Society Series), New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, xiv + 526 pp. $15.

DRYDEN, H. L., AND VON KARMAN, TH., editors; Kuerti, G., managing editor, Advances in applied mechanics, Vol. IV, New York, Academic Press, Inc., 1956, x + 413 pp. $10.

FOURIER, J., The analytical theory of heat (translated with notes by A. Freeman), New York, Dover Publications, Inc., 1955, xxiii + 466 pp. $1.95 (paperbound).

FRANK-KAMENERSKII, D. A., Diffusion and heat exchange in chemical kinetics (translated from the Russian by N. Thon), Princeton,

N. J., Princeton University Press; London, Geoffrey Cumberledge, Oxford University Press, 1955, xii + 370 pp. $6. (paperbound).

HARTMAN, J. B., Dynamics of machinery (McGraw-Hill Series in Mechanical Engineering), New York, Toronto, London, McGraw-Hill Book Co., Inc., 1956, xvi + 283 pp. $7.50.

KÖHLER, E. L., AND LEGAT, A., collaborator, English-German and German-English dictionary for the iron and steel industry [Englisch-deutsches und deutsch-englisches Wörterbuch für die Eisen- und Stahl-Industrie], Vienna, Springer-Verlag, 1955, xii + 168, 162 pp. $6.65.

KOPAL, Z., Numerical analysis, New York, John Wiley & Sons, Inc., 1955, xiv + 556 pp. $12.

MARTIN, W. T., AND REISSNER, E., Elementary differential equations (Addison-Wesley Mathematics Series), Cambridge, Mass., Addison-Wesley Publishing Company, Inc., 1956, xi + 260 pp. $5.50.

MESTSCHERSKI, I. W., Aufgabensammlung zur mechanik (Hochschulbücher für Physik, 13) (translated from Russian), Berlin, VEB Deutscher Verlag der Wissenschaften, 1955, 391 pp. DM 22.

NATANSON, I. P., Konstruktive funktionentheorie (Mathematische Lehrbücher und Monographien, 7) (translated from the Russian by K. Bögel), Berlin, Akademie-Verlag, 1955, xiv + 514 pp. DM 36.

NÉMETH, E., Hidrológia és hidrometria, Budapest, Tankönyvkiadó, 1954, 662 pp. + 32 illus. (paperbound).

NIKOLAI, E. L., Theoretische mechanik, I. (Hochschulbücher für Physik, 21) (translated from 1952 Russian edition), Berlin, VEB Deutscher Verlag der Wissenschaften, 1955, xii + 282 pp. DM 15.30.

SCHÜTTE, K., Index of mathematical tables from all branches of sciences [Index mathematischer tafelwerke und tabellen aus allen gebieten der naturwissenschaften] (in English and German), München, Verlag R. Oldenbourg, 1955, 143 pp. DM 14.50.

SELÉNYI, P., AND JÁNOSSY, L., editors, Roland Eötvös Gesammelte Arbeiten (Eötvös Loránd Összegyüjtött munkái), Budapest, Akadémiai Kiado, 1953, lxxx + 384 pp.

TOLSTOW, G. P., Fourierreihen (Hochschulbücher für Mathematik, 14) (translated from 1951 Russian edition), Berlin, VEB Deutscher Verlag der Wissenschaften, 1955, xi + 300 pp. DM 17.50.